A model for use-centered design of payment instruments applied to banknotes

de Heij, Hans

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

A Model for Use-centered Design of Payment Instruments Applied to Banknotes: Upid-Model

Proefschrift ter verkrijging van de graad van doctor
aan Tilburg University
op gezag van de rector magnificus,
prof. dr. E.H.L. Aarts,
in het openbaar te verdedigen ten overstaan van een
door het college voor promoties aangewezen commissie
in de aula van de Universiteit op

dinsdag 7 november 2017 om 14.00 uur

door

Henricus Anthonius Maria de Heij
geboren op 23 januari 1954 te Haarlemmermeer.

Promotores

Prof. dr. R.J. Berndsen
Prof. dr. F.G.M. Pieters

Commissieleden

Prof. dr. H.A. Benink
Prof. dr. J.W.M. Das
Prof. dr. J. de Haan
Dr. ir. P. Koeze
Prof. dr. J.E. Raymond
Dr. A. Roos
Dr. D. Tidmarsh

PREFACE

The design of Dutch gulden banknotes was - and still is - highly appreciated. The designs were made without an academic model on banknote design. The high design standards were merely the result of quality of the designers, who received plenty of freedom. The design assignment was laid down in a Programme of Requirements, supplemented with lean and mean project management.

I have been working for 36 years in banknote design and made several publications on the topic. After the design and issuance of the euro, the preparations started for the second series of euro banknotes and I was thinking, now that we all have the same banknotes, a major step forward can be made in the professionalisation of banknote design. However, I soon discovered that a structured approach of the design process was not going to happen. It wasn't going in the direction I envisioned and I felt miserable. I went on a course with the title: "Why don't they just do what I say?" and there I learned that there are other ways to gain influence, like publishing. A pinnacle of a publication is a thesis and this idea brought a new challenge into my life. A dissertation on banknote design was never made, let me try!

Banknote design is part of graphic design, a multidisciplinary domain at the intersection of design methodology, consumer behaviour and human perception. Graphic design is also referred to as *2D-design*, a design discipline next to *3D-design*, like architecture and industrial design. In 2008, I started searching for a promotor in graphic design at the Faculty of Industrial Design Engineering, part of Delft Technical University. Several well-known professors have been teaching graphic design at this Faculty, like Wim Crouwel, Robert Oxenaar and Paul Mijksenaar, all examples of the *designer-scientist*. During my career as banknote design manager at DNB, I had the privilege to work with all three. Prof. Crouwel was commissioned to represent DNB in the jury of the design entries made for the first series of euro banknotes (1995-1996), Prof. Oxenaar was the graphic designer of my first banknote design project, the NLG 250/Lighthouse (1981-1986), and Prof. Mijksenaar was commissioned to develop wayfinding symbols for euro banknotes (2003-2005).
Designer-scientists are appointed because of their design successes and not primarily because of their academic achievements. To Prof. Oxenaar, the banknote designed was his main publication; he gave interviews and presentations, but did not publish an academic article on banknote design.
However, in 2008 graphial design was no longer a separate scientific domain and I opted for the alternative offered, the domain of "Applied Design", a chair held by Prof. Ir. Jan Jacobs. In 2008 I was accepted as an external PhD-candidate. In 2012, Prof. Jacobs accorded the emeritus status and in 2015 my thesis was discontinued. Prof. Dr. Ron Berndsen, holding a chair in financial infrastructure, invited me to continue my thesis at Tilburg University. The focus was put on the theoretical foundation of use-centered design of banknotes. Model building starts with observing banknotes as a means of payments, one of the economic functions of money.

I had to pioneer the work, as a sample thesis was not available. I started with in my backpack experience in banknote design and several articles. My main observation was - and still is - that the banknote user is not in the center of a banknote design project. I like to see myself as a *scientist-designer*, connecting the domains of science and design.

The process I went through is a clear example of a search process with a heuristic character. I recognise the drive to complete my work in a 19th century quote: "Do not go where the path may lead, go instead there where there is no path and leave a trail." (Ralph Waldo Emerson, 1803-1882).

What would I like to achieve with this thesis? First, peace of mind as I have trusted my studies to paper, so that they will not disappear. As a scientist, I do hope my thesis will inspire others to build further on academic knowledge on banknote design. Secondly, after reading my thesis, central banks will be better prepared for a banknote design project, moving in a direction of 'fact based design', creating banknotes which will serve the public better.

When bankers come together for dinner, they discuss art.
When artists get together for dinner, they discuss money.
Oscar Wilde (1854 - 1900)

CHAPTER 1
INTRODUCTION

1.1 Introduction

A Model for Use-centered Design of Payment Instruments has been developed in this thesis and is applied to banknotes. The developed Model describes the *interface* between a human and a payment instrument. A payment instrument can be a banknote denomination, for example 20 euro, but may also be a debit card or a wallet app. Payment instruments (euro 20 note) are used within a payment channel (banknotes), which are part of a payment system (cash) and will be explained in more detail in subsection 2.4.2 on means of payment.
The aim of the Model is to provide a description of the reality of a payment from the users' perspective. Furthermore, the Model should be the smallest testable model to design the human interface of a payment instrument. The Model should also deliver a common language, a terminology supporting the design of payment instruments. Finally, the Model should put the user in front of the design of a payment instrument. This is symbolised by the Model's label, the *Upid-Model,* with the letter U in front. Upid stands for *User Payment Instrument Design*. The alliteration of Upid is similar to *Ipad*, a line of tablet computers by Apple, which is seen as appropriate, as Apple co-workers introduced the term User-centered Design (Norman, 1988).

Although the developed Model is applicable to different payment instruments, the focus of this thesis is on banknotes, on banknote design and on measuring a banknote's design qualities from the users' perspective. Banknotes are designed and made available by a central bank for their users. Worldwide there are around 190 central banks, and about 160 of them issue their own currency. Central banks may work together in a monetary union, like for example the 20 central banks of the Eurosystem, which includes the European Central Bank (ECB).
Central banks receive a monopoly position on the issuance of banknotes from their legislator. The design is left to the central bank, phrased as follows in the former Dutch Banking Act (Bankwet, 1948):

> "The denomination and the design of the banknotes issued are determined by the Board of the Bank and notified to the public."

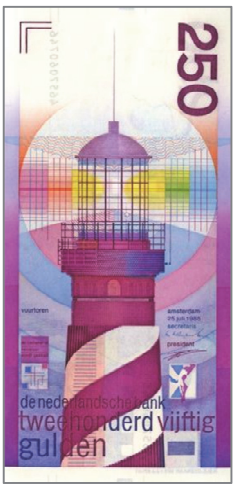
In several cases, a new banknote design needs to be endorsed by the Ministry of Finance or Treasury. Designing their banknotes, central banks follow a 'one size fits all' approach. People cannot opt for a trendy happy banknote design or a senior model with a bigger letter type. Availability is limited too; in front of an ATM people may select from three different denominations, for example 10, 20 and 50 euro. Furthermore, the notes received may be second hand, already used by others.
Banknotes have existed for over 350 years and were designed without an academic model. Academic modelling of banknote design is at its infancy, illustrated by a quote of Eom and Kim (2015):

> "The domain of the design of security documents has been isolated from the mainstream of designdiscourse, because of the extremely limited number of security designers worldwide and a closed and technology-driven design environment."

The Model for Use-centered Design of Payment Instruments is a qualitative model, with the potential to incorporate quantitative parts.
The Upid-Model can be used for the problem definition of a new banknote design. For example, the policy of central banks is to 'maintain the integrity of the currency', but this does not clarify what should be designed and when it is of sufficient quality. Using the Model, targets can be set for each user function. For example, 95 % of the public should score at least 7 for a specific user function, on a scale from 1 to 10.

NLG banknote designs by Robert Oxenaar
1965 - 1986

a)



b) c) d)

Figure 1.1
Banknotes designs by R.D.E. Oxenaar (1929-2017). Portrait, part of Series Forebears II (a) and House-Tree-Animal Series (respectively d, b and c).
a) NLG 1,000/Spinoza, issued in 1973
b) NLG 50/Sunflower, issued in 1982. Design together with J.J. Kruit.
c) NLG 100/Snipe, issued in 1981.
d) NLG 250/Lighthouse, issued in 1986. Design together with J.J. Kruit.

NLG banknote designs by Jaap Drupsteen
1989 - 1997

a)

b)

c)

d)

Figure 1.2
Banknote designs by J.T.G. Drupsteen (born 1942). Abstract Series.
a) NLG 10/King fisher, issued in 1997.
b) NLG 25/Robin, issued in 1990.
c) NLG 100/Little owl, issued in 1992.
d) NLG 1,000/Lap wing, issued in 1994.

Summarising, the Upid-Model applied to banknotes provides a framework for the:

1) Creation of new user friendly banknote designs,
2) Reporting measurements following the Model's user functions,
3) Management of a banknote design process,
4) Organisation of development projects related to banknotes (Research & Development, R&D),
5) Explanation of the design history of banknotes.

The thesis elaborates on 1) and 2) only.

Banknote designs of the Netherlands gulden (NLG) are shown in the figures 1.1 and 1.2, designs delivered by respectively Robert Oxenaar and Jaap Drupsteen. Both designs are appreciated by the Dutch as will be elaborated on in section 6.7. The designs made by Oxenaar were judged as iconic, both nationally (Staal and Wolters, 1987; Kuijpers, 2011), and internationally (Cramsie, 2010). Drupsteen delivered a new approach, as it was his opinion that Oxenaar's designs could not be improved.
The Dutch designers used their intuition and creativity. Their way of working is not transferable and not verifiable, and therefore classified as intuitive, as non-academic. An academic model was also not at hand for the *banknote design management*. Instead, De Nederlandsche Bank (DNB), applied the following three *principles*:

1) Invite the best Dutch graphic designer,
2) Provide a high *design freedom*,
3) Support the designer.

Both designers, Oxenaar and Drupsteen, were selected by a design contest based on invitation (Bolten, 1999). Three candidate designers participated in the 1965-contest for a design for a 5 gulden denomination. Six designers were invited for the 1986-contest for a new series of gulden banknotes.

The concept of design freedom is shown in figure 1.3 (De Heij, 2012; 2014; 2017). Artists feel attracted to the highest level of design freedom (level 10), which is the case with private initiatives. However, no cases are known of central banks leaving the designer completely free. Dutch banknote designers were free within the frame of a brief *identity description*, a design freedom classified at level 9. The participating designers of the latest Swiss banknote design competition received the motto "Switzerland open to the world", indicating level 8 (Swiss National Bank, 2005). Other central banks provide lower levels, like in case of upgrade designs of euro (level 4) and US dollar (level 3). Only changing the signature is indicated by level 1.
Experiences with a high design freedom are not always successful. De Rivaz (1997) stated that the major reason for three unsuccessful design competitions in Switzerland was the design freedom. Better results were achieved with defining the theme and including the whole series in a design competition.

Designers want to design and don't want to be bothered with bureaucratic paper work or meetings, so is the author's experience (De Heij, 2017). They also seem to have an aversion of formal design methods. On the other hand, designers want to know what they have to design. A common method to list design requirements is a Programme of Requirements or PoR (Roozenburg and Eekels, 1995). The PoR is the linking pin between the product domain and the process domain, as illustrated by figure 1.4 (De Heij, 2008b; 2010c; 2017). The PoR is the responsibility of the central bank's *banknote design manager*, while the design itself is the responsibility of the designer. The Model for Use-centered Design of Payment Instruments provides a framework for the content of the PoR for banknote design.

DESIGN FREEDOM OF BANKNOTE DESIGNERS			
	Level	**Policy**	**Example**
Free	10	Completely free	Private initiatives, e.g. DollarReDe$ign Project (2009)
	9	Identity description	Netherlands (since 1976)
	8	Prescribed new motto	Switzerland (2006), Aruba (2014), Norway (2014)
	7	Prescribed new theme	Denmark (2006)
	6	Prescribed new main subject	France (1982), Israel (2011), Sweden (2011)
	5	Keep motto	-
	4	Adapt main image	Euro (2013), United Kingdom (since 1960)
	3	Keep main image	Brazil (since 1994), Chili (since 1996), USA (since 1929)
	2	Keep lay-out	Lebanon (since 1994), Poland (since 1994).
Bound	1	Minor change	Signature change: euro, USA. Adding names of portraits: Australia. Change foil: Japan.

Figure 1.3
Model for the Design Freedom of Banknote Designers. Banknote designers may receive different design assignments from central banks; from an upgrade to a completely free assignment. Design freedom is not only a factor during the phase of the design setup, but should be maintained up to the very last correction of the production process.

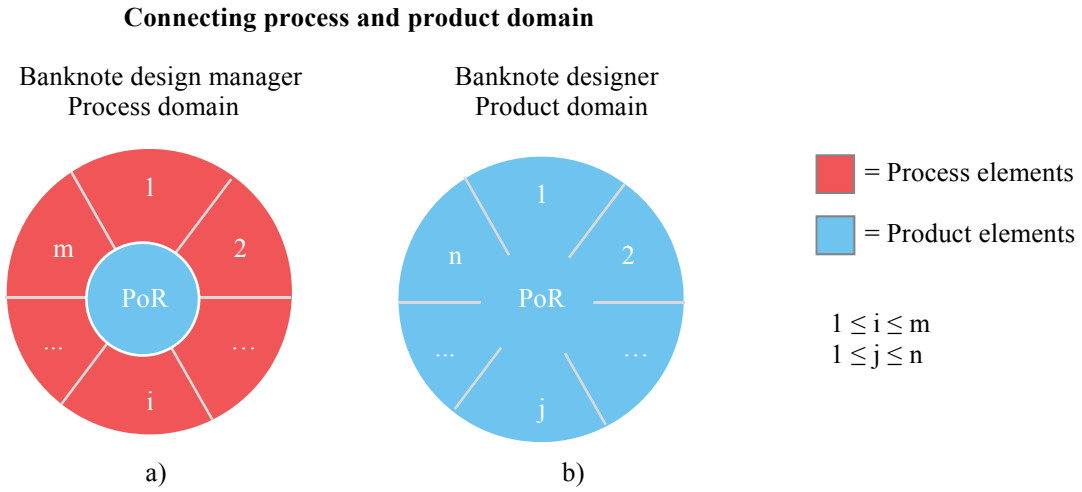


Figure 1.4
The central bank oversees the design process and the designer is responsible for the design. Linking pin between process and product is the Programme of Requirements for a New Banknotes, a tool to make a clear separation between the responsibilities of the central bank and the designer.
a) The process to come to the design is described in several separate planning topics (n), like quality, time, budget, information and organisation.
b) The product to be designed is described in the PoR, divided in several main topics (m), for example, following the user functions of a banknote as described in the Upid-Model.

The Upid-Model creates a common language, providing a terminology to banknote design, clarified by an example of Dutch banknote design. In 1989, a new 25 gulden was issued, designed by Jaap Drupsteen (figure 1.5d). The transition from the old (figure 1.5c) to the new was clear, the portrait was replaced by a graphic grid. The portrait of a historical person contributes to 'recognising identity', while the graphic grid supports 'recognising value'. Furthermore, 'connecting to the main image' remained unused in Drupsteen's designs, as he questioned the function of a main image. Earlier, a similar transition was carried out for Dutch coin design (figure 1.5a and b). In anticipation of the introduction of the terms of the Upid-Model in subsection 2.5.2, the design transition of Dutch banknotes can be identified as a shift from UXF 1 to UIF 1.

It is the author's observation that modern banknote design is dominated by technical topics like production and detection. The focus is not on the public, the main end-user. Therefore, a *use-centered design policy* is proposed instead of a *technology-driven design policy* (figure 1.6). Retailers are in this thesis also identified as an end-user, as they receive the banknotes brought in by the public.
Other users of banknotes are stakeholders, as will be clarified in subsection 1.3.1.
Use-centered banknote design has not (yet) reached central banks, so is the underlying statement of this thesis. Central banks have a monopoly on banknote design and depending on who is in charge, the banknote design process is either dominated by a *cashiers' view* or by a *printers' view* (De Heij, 2007). Characteristic for a cashier's view are production costs and durability, while with the printer in the driving seat, the focus is on authenticity features, automatic processing and Quality Assurance. A cashier's view, so is the author's observation, tend to a paternalistic attitude of 'father knows best'. And a printers' view often reminds us of the quote of Henry Ford (1863-1947): "Any customer can have a car painted any colour that he wants so long as it is black" (Ford and Crowther, 1922). This thesis advocates for the replacement of the cashiers' and printers' view by a *users' view*, a design policy focussing on the two main end-users of a banknote, the public and the retailers.

Central banks are making efforts to move away from technology-driven designs. According to the Swiss National Bank "a banknote must be user-friendly" (Wettstein and Lieb, 2000). The central bank of Canada analysed that (Firth and Church, 2009):

> "The approach of the private sector, because it is largely driven by profit motives and short term timelines, is not completely suitable for the Bank of Canada".

And the following statement is made by the central bank of India (Krishnaswamy, 2012):

> "The transformation from centrally designed by in-house designer to public participation for indigenous designing of banknotes can be effected gradually but steadily".

Academic literature on banknote design is limited and does not deliver insights in the methodology of banknote design. Dissertations on banknote design do not exist. In a thesis by a well-known Dutch letter designer, the design considerations of a new typographic font are described, named Alverata (Unger, 2013). However, Unger's study did not provide any design methodological tools which could be applied for banknote design, an illustration of the designer-scientist approach.
Since the 1990s, central banks provide more background information on their banknote designs. One of the few documents on model building of *security documents* like a banknote, is the publication by Eom and Kim (2015), already referred to. They suggest organising a banknote design project from a communication perspective, as in their view banknote design either focusses on identity or on technologies for deterring counterfeits. However, this thesis demonstrates that, next to communication, there are nine other user functions.
More common are empirical studies on specific design elements. An example is a study published on tactile features, assisting the blind to denominate banknotes (Lederman and Hamilton, 2002). Another example is the yearly report on the confidence of Canadians in their banknotes, providing longitudinal data (Bank of Canada, 2016b).

From UXF 1 to UIF 1

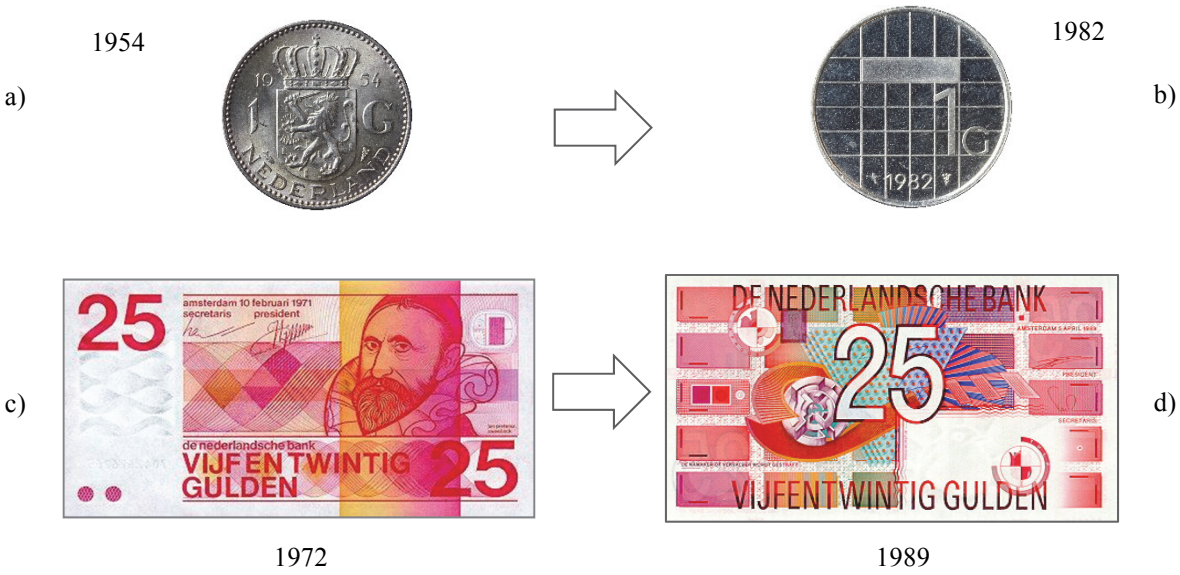


Figure 1.5
Main images on Dutch coin and banknote design developed from symbols and historic portraits (in the Model UXF 1) to images supporting the recognition of the value (UIF 1).
a) Coin with coat of arms (issued 1952, designer Oswald Wenckebach (1895-1962)).
b) Coin design with grid supporting value recognition (issued 1983, designer Bruno Ninaber van Eyben).
c) Banknote with portrait (issued 1972, designer Robert Oxenaar).
d) Banknote design with grid supporting value recognition (issued 1989, designer Jaap Drupsteen). Twenty five units for the 25 gulden, hundred units for the 100 and so on.

Banknote design policies

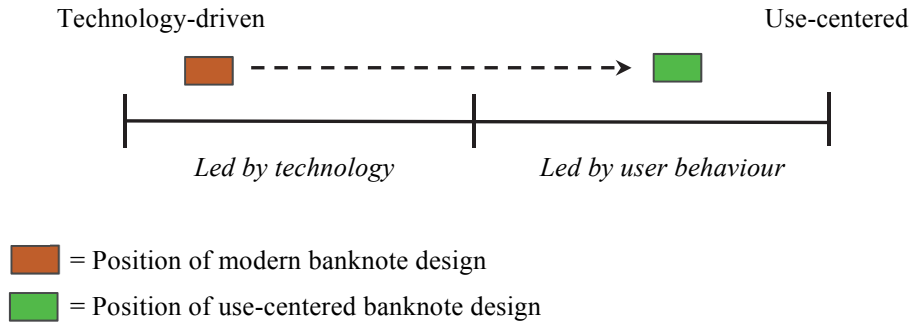


Figure 1.6
Imaginary scale of banknote design policies with on the extreme left a technology-driven banknote design policy and on the extreme right a use-centered banknote design policy. Modern banknote designs operate on the left side of this spectrum, focusing on production techniques and logistics. The aim of use-centered banknote design is a position on the right, led by user behaviour.

Over the years 1981-2017 the author initiated a variety of studies focussed on the use of banknotes by the Dutch public, all commissioned by DNB. These studies have been brought into the public domain, an overview is provided in Appendix 1, split into gulden banknotes (1983-2001) and euro banknotes (2002-2017). At first these studies were published in DNB's own magazine (e.g. De Heij and Koeze, 1986), followed by publications within professional literature (e.g. De Heij and Koeze, 1988; 1992) and presentations at international conferences (e.g. De Heij, 2000; 2002; 2008a). A next step was to summarise these publications and to bring them to a higher abstraction level, which was part of the *field work* of this thesis. The following three publications were made within DNB's Occasional Studies:

1) Banknote design for the visually impaired (De Heij, 2009).
2) Banknote design for retailers and public (De Heij, 2010a).
3) Designing banknote identity (De Heij, 2012).

Afterwards, it turned out that these three publications represent three of the User Functions of the Upid-Model developed, respectively value recognition (UIF 1), checking authenticity (UIF 3) and experiencing identity (UXF 1).
During the thesis period, a fourth major publication has been produced, a book published by the International Banknote Designers Associaton (IBDA), located in Lausanne:

4) The Banknote Designer and the Banknote Design Manager. Who does what? (De Heij, 2017).

This publication deals with topics on banknote design management, on the *how*, and the focus of this thesis is kept on the *what* should be designed. One of the leading thoughts of this thesis is: What will be the instruction of the central bank to the just appointed banknote designer? Therefore, the last pages of the last chapter list the requirements for a new banknote from the public's perspective, using the present knowledge of the author.

Other findings within the thesis period have been published in several articles, like "The 4M-model for Banknote Designers" (De Heij, 2015b) and "User Experience Functions (UXFs) and User Interface Functions (UIFs) of Optical Authenticity Features" (De Heij, 2016d). The reference paragraph includes an overview of the author's articles.

1.2 Literature on banknote design

Since the 1990s, several central banks published background information on the development of their banknotes. Although there is a trend to openness, an academic discourse on banknote design is absent and literature on banknote design remains limited.

1.2.1 Trend to openness

An early example of openness on currencies is a placard published in 1626 by the Republic of the Seven Provinces, as the Netherlands were called in these days. The poster provided an overview of all 388 coins, domestic and foreign, allowed in the Republic (De Nederlansche Bank, 2010a). A similar example dates back to the days of private banknotes in North America, around 1850, where catalogues were prepared to provide openness on the myriad of banknotes issued by commercial banks. The need for information on current banknotes, new issues and recalls, still exists today and is provided by "The MRI Bankers' Guide to Foreign Currency", of which the first issue was published in 1990.
Collectors are another precursor interested in background information of banknotes. Since 1957, they may find numismatic news and information on banknotes in "Bank Note Reporter Magazine". Since 1961, such information is also delivered by the "International Bank Note Society Journal".

Since the 1990s, central banks experience more public pressure to disclose information on banknote designs. Four drivers encourage this process: governmental 'right to know' policies (1), the emerge of the internet (2), science (3) and patents (4). Started at the late 1970s, central banks communicated authenticity features to the public, which may also have encouraged more openness.
Information on banknote designs is brought into the public domain, as for example practised in the Switzerland and the Netherlands. Access to the worldwide internet, the second driver, became general available just before the year 2000. Information provided by the internet is spread fast, information leaks could no longer be avoided or stopped. Science is the third driver to openness. Knowledge on banknotes is brought further by an academic approach, building further on studies done by others, an approach followed by the central banks of Canada and the Netherlands. Finally, patent applications, mainly describing authenticity features, contribute to openness. It is not very likely that criminals will profit from such abstract technical descriptions as patent applications are.

Early *academic* publications on banknotes include studies on the banknote's life (e.g. Koeze, 1979; 1982a). In 1986, DNB published a bundled series of academic articles aiming for a scientific approach of banknote topics, including its design (Fase et al., 1986). A video portrait of Dutch gulden banknotes was broadcasted that same year, directed by Jaap Drupsteen, which was the result of a cooperation between the AVRO, one of the Dutch television channels, and DNB (Drupsteen, 1986).

The trend to openness on banknotes, including its design, continued with the introduction of conferences, which were mainly initiatives of the currency security industry, some supported by a central bank. Examples are the "Currency Conference" (first in 1992), the "Banknote Conference" (first in 1998) and the "Watermark Conference" (first in 2006). An independent and scientifically oriented conference is the "SPIE Optical Security and Counterfeit Deterrence Techniques" (first in 1994), transformed in 2008 to "Conference on Optical Security and Counterfeit Deterrence". Topics presented at these conferences have been published in an academic book on optical authenticity features (Van Renesse, 1994; 2005).
Openness on banknotes continued with the introduction of periodicals, like "Infosecura" (first in 1996), "Banknotes of the World" (first in 1999), "Currency News" (first in 2003), "Keesing Journal of Documents and Identity" (first in 2003), "Watermark Digest" (first in 2007) and "Billetaria"(first in 2007, discontinued in 2015).
The trend to openness on banknote topics was picked up by a journalist, who unveiled the 'secret world' of banknote printers (Bender, 2004). The term 'secret world' was already used before, in "The Brotherhood of Money: The Secret World of Banknote Printers" (Bloom, 1983).
In 2011, the International Banknote Designers Association (IBDA) was established, one more initiative to create transparency in the world of banknote design, including a newsletter named IBDA-News (first issue in 2011). A specific publication contributing to openness is a report on the creation of the euro banknotes by a former Director Banknotes of the European Central Bank (Heinonen, 2015).

Up to the early 2010s digital information was filed on hardware like CD-ROMs and USB-sticks. Developments in the digital world made it possible to store information 'in the cloud', accessible at any time and any place. This development triggered in 2014 the initiative of DNB to launch a digital platform for studies published on payments systems, including cash, called "DNB Payments Scholar".

1.2.2 Publications on banknote design

Popular publications on banknote design dominate over academic studies and their focus is usually on the images displayed. Without being able to present a complete overview, the following is an impression of the publications.
Engineers seem to have been the initiators of early publications on banknotes, like the gravure technique (Dickinson, 1895). About hundred years later another engineer, Koeze (1982a), published on the technique of constructing moiré patterns, the 'screen trap', as applied in the large circle in the background of the NLG 100/Snipe (figure 1.1c).

Central banks began publishing on their banknote designs in the 1960s, like the central bank of Sweden (Lindgren, 1968). The Danish central bank followed with a publication on the aesthetics of Danish banknotes (Andersen, 1975), a publication in conjunction with the issuance of a new Danish series. The first catalogue of paper currency was published, covering all nations, from Afghanistan up to Zimbabwe (Pick, 1975). Updates are yearly issued as Standard Catalog of World Paper Money (Pick and Schmidt, 2017). Each entry contains photographs of the front and back, identifying information and current market value for collectors. Images of banknotes from all over the globe were also the theme of a publication by Monestier (1983). In the late 1980s several publications appeared on a country's currency history, studies interlarded with lots of anecdotal information, like on the history of Dutch coins and banknotes (Jacobi and Van Beek, 1988) and one focussing only on Dutch banknotes (Grolle, 1991). A publication on general aspects of banknote design was published by the Austrian National Bank (Kranister, 1989). In this same category belongs a publication on a "tour of cash for design aficionados" (Standish, 2000).
An academic design study concerned Dutch banknote designs issued between 1814 and 2002 (Bolten, 1987; 1999), a study ordered by DNB on the occasion the celebration of its 175th anniversary. The study described in detail the relation between central bank, printer and designer. An earlier resume was part of the Monetary Monographs (Fase et al., 1986). The Bank of England published in these same years, the history of their banknotes, anticipating their third centenary in 1994 (Hewitt and Keyworth, 1987). Other publications from those years concern the design and production process of banknotes (Deutsche Bundesbank, 1995) and a comprehensive publication on Swiss banknote design (De Rivaz, 1997). The introduction of the euro triggered central banks to dedicate a publication to their banknotes, like in Finland (Talvio, 2003) and Spain (Banco de España, 2004). Other central banks followed, like Turkey (The Central Bank of the Republic of Turkey, 2005) and Chile (Banco Central de Chili, 2009).
Banknote printers also published on banknote designs, like the American Banknote Company (1961), the Polish printing works PWPW (Folga-Januszeweska, 2006), the Russian Goznak (Trachuk and Nikiforova, 2008) and the German Giesecke & DeVrient (Jungmann-Stadler and Devrient, 2009). When the euro banknotes were issued in 2002, a first design analysis was already available (Brion and Moreau, 2001). This publication could only analyse the winning design by the Austrian banknote designer Robert Kalina (born 1955), as the other entries of the 1996 design contest were released in 2003 (European Central Bank, 2003). This catalogue includes all 44 designs, prepared by 29 designers, a milestone in the publications on banknote design, although any explanation or analysis was not part of it.

Hymans (2004) seems to be the first to publish an overarching analysis of the design history of European banknotes, an academic study on themes applied to banknotes, distinguishing five currency issue epochs. An impression of banknote designs in the 19th century by printing works in the United States is provided by Tomasko (2012; 2014).
A need for more insight into banknote development was experienced by the International Monetary Fund (IMF) in the 1990s, when currencies had to be introduced in new countries, mainly former parts of the Soviet Union (Abrams, 1995).
A contemporary picture of how the Bank of England perceives banknote design was prepared by Salmon (2011).
A recent contribution on bank design analysis discriminates six different *Style Groups* (Payne, 2016).

A separate category are publications about counterfeiting, which regularly refer to banknote design. One of the first is a novel by Bloom (1953), "The Man Who Stole Portugal". Bloom has been introduced (subsection 1.2.1) and made also a publication on 'the greatest counterfeiters' (Bloom, 1982). One of them was forced to take part in Operation Bernhard in 1944 and published a book about his experiences (Nachtstern and Arntzen, 1949). In 2007, this novel has been made into film (original title "Die Fälscher"). One more counterfeiter published a novel on his activities (Bourassa and Warren, 2016). In 2009, Bourassa managed to order security paper and used it to print a large volume of fake USD 20.

McCabe (2016) published a comprehensive book on 'counterfeiting and technology' of paper money in North America and includes an historic overview of the development of banknotes up to the year 1900. This publication includes many images of banknote designs, but doesn't elaborate on the design principles behind them. In a chapter named "The Bad Boys" McGabe provides an extensive overview of counterfeiters active in North America roughly between 1765 and 1900.
Crowley (2016) reviewed the ten most notorious counterfeiting operations between 1915 and 2015.
Kersten (2009) published on the relationships between crime and family and the destructiveness of greed within the life of a professional counterfeiter of US dollars.

1.3 Limitations and choices

Banknote design is a multidisciplinary topic and this first thesis on the subject must be demarcated. The introduction of this chapter already reported that topics on design management are not part of this thesis. Other topics kept out are reported in this section, like the user needs of stakeholders. The focus of this thesis is on the public and not on stakeholders (subsection 1.3.1). Subsequently, the drivers for a new banknote design are listed, once more focussing on the needs of the public (subsection 1.3.2). Banknotes have existed for more than 350 years and much can be learned from their history. However, the history of banknote design is limited to a short historic review (subsection 1.3.3). Finally, a series design is kept outside the scope of this thesis and is only briefly introduced (subsection 1.3.4).

1.3.1 Public is the end-user of banknotes

The European Central Bank (2004a) identified *customers* and *users* of banknotes, although the difference between the two was not clarified, as follows:

> "(…) the general public (including the visually impaired), cashiers, vending machines, banknote processing machines, cash handlers, law enforcement authorities and the note-issuing authority itself. Each has different needs in terms of convenience, authentication, efficiency, resilience and cost, and these needs also differ for low, medium and high denomination banknotes".

User groups are identified by De Heij (2007), dividing user groups in *primary user groups* and *secondary user groups*. Three primary user groups are distinguished: public (1), retailers (2) and counterfeiters (3). Secondary user groups are law enforcement (1), press (2) advertisement agencies (3) and collectors (4).
The focus of this thesis is on one user group, the *public.* Incidentally the thesis also reports on the *retailers*, which are the second user group of banknotes. Retailers are the people behind the check-out counters, the one with which the account is settled. Retailers are usually classified as one of the subgroups of *Cash Handlers,* which also includes cashiers and vending machines.

By number, the largest user group is the public. However, when the focus is on handling, retailers are the main user, illustrated by figure 1.7. Retailers in the Euro Area handle on average about 120 banknotes per day, of which 20% receives more than 200 banknotes a day (TNS/NIPO, 2004; reported in De Heij, 2010a). Payment behaviour in seven different countries, including the Netherlands, has been studied by Bagnall et al. (2014), reporting that people make a payment once or twice a day. These figures are in line with a Dutch study (Hoevenagel et al., 2015) reporting that the public visits two times a day the counter of a retailer, known as a *Point-of-Sales* (POS). This study also reported that most of the Dutch retailers (70 %) receive more than 50 payments a day, while 10 % of the retailers receive more than 1,000 payments a day.
Aiming for the public, the title of this thesis may also be read as "A Model for *Public*-centered Design of Banknotes". However, such a title does not connect to existing literature, as will be elaborated on in subsection 2.2.1.

Banknote user groups are split in primary and secondary user groups and all others are classified as *stakeholders*. Users *use* banknotes to pay each other and stakeholders provide the *infrastructure for the usage* of the banknotes. The main stakeholders are listed in figure 1.8: producers (1), transporters (2), distributers (3) and equipment manufacturers (4).
Users and stakeholders are connected, for example, when the public inserts a banknote into a payment terminal; the public is the user, the provider of the terminal is the stakeholder.
On a daily basis, stakeholders handle much more banknotes then private persons or retailers do. Employees of a *banknote printing works* may process on one day two million banknotes or even more. People working in vaults or for *Cash in Transit companies* (CiTs) will reach even higher volumes. In such working situations banknotes are no longer single pieces, but logistical units, like bundles, containers and pallets.
Most stakeholders process banknotes by *banknote machines,* people fill *Automatic Teller Machines* (ATMs) also known as *Cash Machines*. They empty *banknote acceptors*, *Cash-in Machines* and *Cash-Recycle Machines.* They maintain *Banknote Authentication Devices* (BADs) and operate *Banknote Sorting Machines.* For transport and other logistics CiTs are delivering their services. Stakeholders can be grouped together, like the *Banknote Equipment Manufacturers (BEMs).*

In order to allow the introduction of a new banknote smoothly in an increasingly technical environment, central banks to develop 'outreach programs' to communicate and engage with key stakeholders. Such programs should ensure that people may pay with the new issued banknote, for example to the banknote acceptor at the entrance of a toll road or parking garage. As the introduction of the euro in 2002 was a major change, the European Central Bank informed stakeholders 18 months in advance (Heinonen, 2015, page 111). At the time of the introduction of the second series of euro banknotes, it was expected that 6 months would be enough time for the stakeholders, and especially for the BEMs, to be ready for the upgraded euro 5 (issued in 2013). The Reserve Bank of Australia held a same period of 6 months for the introduction a new series (Evans et al., 2015). In case of the euro banknotes, this period of time proved to be too tight and was increased to 9 months for the upgraded euro 10 (issued in 2014).
When a central bank informs their stakeholders, this does not imply that the public and retailers participate in the design process of banknotes. Up to the years 2010, central banks did not involve stakeholders in the banknote design process (Giori, 2014).

1.3.2 Drivers for new banknote design

There are several reasons for designing a new banknote, as listed in figure 1.9. The most frequently heard is technical: new banknotes must be developed to stay ahead of the counterfeiter.
Another reason is the succession of a monarch or another ruler displayed on a banknote, for example in Saudi Arabia when Abdullah became the successor of King Fahd in 2005. The fall of a ruler may also trigger a new series of banknotes, like in 2003 in Iraq. In Taiwan, new banknotes were triggered by a cultural driver; the 'Chinese imagery' was replaced by a 'Taiwanese imagery' (Hymans and Fu, 2016).
An example of an economic cause is the need for higher denominations, because of moderate inflation. High inflation may lead to a monetary reform, an operation referred to by banknote designers as 'dropping zero's'.
The introduction of *Legal Tender Notes* in the USA in 1862 is an example of a legal reason. Rather than guaranteeing the right to be exchanged for gold, these notes proclaimed to settle all "taxes and other public dues". Guaranteed by the government this type of money is called *fiat money*, opposite to *commodity money*, which is money whose value is associated with the material of which it is made, like coins made of silver or gold (Nelson, 2009).
The number of counterfeited banknotes in Norway is negligible. Still, the central bank decided in 2010 to bring the authenticity features on the same level as its neighbours, in case Denmark and Sweden.
An example of a political development triggering new banknote designs is the introduction of the euro banknotes in 2002. The disintegration of a state is also a reason for new banknote design, like in case of the Soviet Union in 1991 and Soudan in 2011.

RECEPTION OF DENOMINATIONS BY PUBLIC AND RETAILERS			
User group	**Received number** banknotes/day	**Received denominations**	
		Regular	Irregular
Public	1 or 2	Payback (5, 10, 20)	High ATM (50)
Retailers	Average 120	High ATM (50)	High denominations (100, 200, 500)

Figure 1.7
Characteristics of banknotes received by public and retailers in the Netherlands.

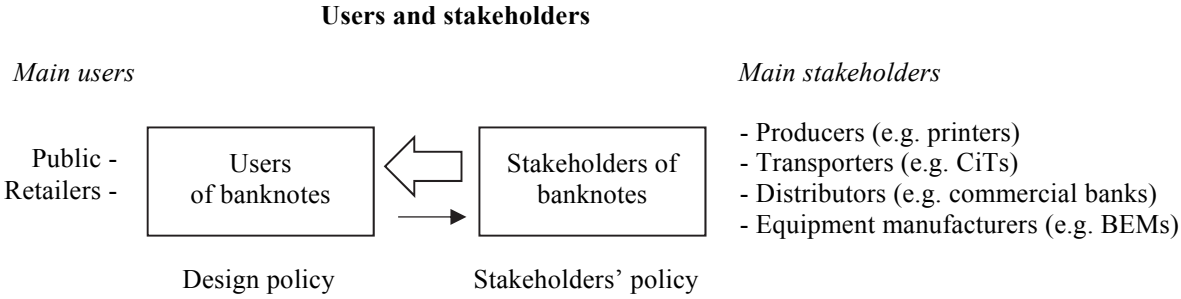


Figure 1.8
The relation between a design policy and a stakeholders' policy. The small arrow represents the underdeveloped user feedback to the stakeholders.

DRIVERS FOR NEW BANKNOTE DESIGNS			
Driver	**Examples**		
	Why	**Currency**	**When**
Change of ruler	New king	Saudi riyal (SAR)	2000
Cultural	Cultural mismatch	Taiwan New Dollar (TWD)	2000
Economic	Redenomination by removal of six zeros	Second Turkish Lira (TRY)	2009
Legal	Legal tender	US dollar (USD)	1862
Neighbours	Neighbours come with new notes	Norwegian krone	2017
Political	Joint currency	Euro (EUR)	2002
Social	Equal display of women and men	German D-mark (DEM)	1989
Technical	Polymer substrate (longevity)	Australian dollar (ASD)	1988
User friendly	Serve user needs better	?	?

Figure 1.9
Overview of various developments triggering the start a new class of banknote designs.

Examples of a social driver for new banknote designs are often linked to another reason, like the introduction of a female portrait on a Japanese banknote in 2004, realised with the introduction of a new denomination of JPY 5,000.
The last row is assigned to user friendly designs.

There are several reasons to design a new series of banknotes. Usually, a new banknote design replaces an existing design, which has circulated for several years. The time that a banknote has been in circulation is the *product lifecycle,* which plots the number of products sold against time, as first introduced by Levitt (1965). In case of banknotes, the product lifecycle is also referred to as the *issue cycle* or the *replacement cycle*.
Modern central banks aim for an issue cycle of seven years (US Federal Reserve System, European Central Bank, South African Reserve Bank). The NRC-report of 1993 advised a five-year cycle (National Research Council, 1993). This report was published at the time of the widespread of digital reproduction equipment like colour copy machines (1987), home printers (1990) and home scanners (1993). To the issuer of US banknotes, the US Federal Reserve System (FRS), a five-year issue cycle was a too short and instead they opted for seven years. However, also a seven years replacement cycle turns out to be too ambitious. The time needed to replace recent dollar and euro banknote models came out on 17 years (1996-2013) for the USD 100 and on 11 years (2002-2013) for the euro 5. Successive euro denominations arrived with a frequency of one or two years. The last upgrade of euro banknotes, the euro 200, will be issued in 2019, bringing a lifecycle of 17 years for this denomination. New Swiss banknotes were announced in 2005 and had to wait until 2016 before the first new design could be issued (Swiss National Bank, 2005), bringing a life cycle of 22 years (the new CHF 50 replaced the design issued in 1994). Still, central banks, may express the intention to change their authenticity features every 3 to 4 years, like recently in India (Press Trust of India, 2017), in case a reaction to India's problematic counterfeit situation.

The urge for short replacement cycles of banknotes was not always there. In the past central banks tended to be comfortable with long life cycles, as it would support trust in the currency. The US dollar is an exponent of this policy, which circulated for 67 years (1929-1996) before three denominations received an upgrade (USD 20, 50 and 100). The USD 5 and 10 followed in 1999 and the one dollar remained unchanged, just as the hardly used USD 2. The German Mark is another example of a long product life cycle. The first series issued by the Bundesbank in 1960, displaying portraits by Albrecht Dürer (1471-1528) and was becoming replaced as of 1990, bringing the D-Mark's lifecycle to 30 years.
Arguments for a lower and an upper limit of an issue cycle can be provided. A *lower limit* to a banknote's replacement cycle is set by the design period, which is about 1.5 years (De Heij, 2000; 2017). If the results of development projects should be incorporated into the banknote design, a banknote development takes about 2 years. When a series of 5 denominations should be replaced, in succession, this would take 10 years. In case of a serial approach this may be reduced to 3 or 4 years.
An *upper limit* for a banknote's replacement cycle may depend on several criteria, like the public's appreciation or the counterfeit threshold. Another criterion is the expiration of a patent, which is usually after twenty years.

Modern banknotes don't face a new *technical threat* of being reproduced, but a *usage threat*. Users turn their back towards cash, as other means of payments offer them better services, as will be elaborated on in section 8.2.
Therefore, following a use-centered design policy, modern issue cycles should be adapted to the user needs and less to the availability of new authenticity features, so is the author's opinion.

The public does not seem to be enthusiastic towards a new series of banknotes, as reported by studies done in Japan and in the Netherlands (figure 1.10). Between 1995 and 2015 the Japanese consistently replied that their banknotes did not need to be redesigned (> 70 %), while fewer than 7% felt that they did (Ministry of Finance of Japan, 2015; Hymans, 2005). The Dutch show a quite similar attitude; in 2009 only 15 % is in favour of a new series (De Nederlandsche Bank, 2009; De Heij, 2010a).
Listening to the public, it seems that central banks should keep the adage in mind: "If it isn't broke, don't fix it".

Zooming in further on the public needs, the first question is whether the public still wants to pay with banknotes. The answer seems to be: 'Yes, but less'. The use of cash in the Netherlands dropped in 2015 for the first time below 50 % of all POS-payments and is expected to decline further to about 40 % in 2018 (De Nederlandsche Bank, 2016). The hegemony of a cash society is gone, not only in the Netherlands, but also in other countries, especially in North-West Europe.

PUBLIC NEED FOR NEW BANKNOTE DESIGN		
	Japan 1995 - 2015	**Netherlands** 2009
No	> 70 %	49 %
Yes	< 7 %	15 %
Don't know/Does not care	< 23 %	36 %

Figure 1.10
Attitude of the public towards new banknote designs.
Question in Japan: Should the banknotes be redesigned?
Question in the Netherlands: Do you think it is time for a new series of euro banknotes?

1.3.3 History of banknote design

A comprehensive publication on the history of banknote design has not been identified (subsection 1.2.2). An overview of the history of money from ancient times to the present day is published by Davies (2002). A short review on "Lessons for Today from the History of Money" has been provided by Heinonen (2009b).
Banknote designs do not seem to follow common classes of Art History, like Arts and Crafts (second half 19th century), Jugendstil, Modernism (both late 19th century, early 20th century), Art Deco (first half 20th century) or others, like Pop Art (late 1950s).
The banknote design history can be described by the historical developments of the user functions of banknotes. However, this exercise needs careful study and is kept outside this thesis. As a first thesis on banknote design cannot do without an impression of the more than 350 years of design history of banknotes, this subsection provides some observations. The observations relate to the developed Upid-Model, user functions are indicated by their codes, like UIF 1 and UXF 2, as will be explained in subsection 2.5.2.

In the past, people paid each other with *original money* or *primitive money*, like shells and salt or tea bricks. Around 700 BC the first coins arrived. The first paper money was introduced in China in the 7th century, a *promissory note*, easing the handling of coins (UIF 2). The issuer promises in writing to pay a determinate sum of money to the depositor, which could be any amount (UIF 1). The Chinese word for coins is *kesj*. Medieval Europe heard for the first time about this type of paper money, appropriately dubbed as *flying cash*, through Marco Polo (1254-1324).
The first paper money in Europe was introduced in the 13th century, not a promissory note, but a *letter of credit*. The Knight Templars used this type of paper money to support their crusades to the Holy Land (1129-1307). Pilgrims deposited their valuables at a local, trusted Templar, before embarking. From the Templar, they received a document indicating the value of their deposit. Upon arrival in the Holy Land, and at places passing, the letter of credit was used to retrieve their funds. During their journey, the deposited coins remained in secure storage, in Italian called "cassa". "Kassa" is still the Dutch word for cash register.

Banknotes are a further development of the promissory notes. For promissory notes to become *bank notes* or *banknotes*, first banks had to be established, which goes back to the 12th century. In 1472, the Banca Monte dei Paschi started in the Italian town of Siena and is the oldest, still existing bank. Stockholms Banco in Sweden was the first bank that issued banknotes, in 1661. The novelty of banknotes was that *anyone* who would return a banknote to the bank received the indicated value in coins, in silver or gold. This service was clearly written on British banknotes: "I promise to pay to bearer on demand the sum of ...". As banknotes were payable to anyone, fixed denominations were introduced (UIF 1). Merchants could operate an authenticity self-check by verifying several authenticity features such as a watermark and a seal (UIF 3).

The first banknote designs were typographic designs and over the decades their designs changed. In case of Dutch banknotes, ten different design periods have been identified (De Heij, 2012). When these periods are analysed on their *design theme*, several periods can be grouped together, presenting a general *Classification of Banknote Design Periods,* representing six periods (figure 1.11). This classification builds further on the work of Hymans (2004), who distinguished five *currency issue epochs*, analysed by the design themes applied to European banknotes. The proposed classification is a start for further study, as worldwide banknote designs differ from each other, especially in the periods before 1970.
The following will introduce each period in short.

Early banknotes are *typographic designs,* characterised by texts, signatures, seals and ornaments.

The Great Exhibition of 1851 in London was a showcase of the results of the ongoing Industrial Revolution. The banknote designs of this period, with the proposed name *Prosperity*, suggest that the use of banknotes supports economic welfare (UIF 4), expressed by images of ships under sail or smoking chimneys. The main stream of the designs prepared within this period are characterised by symbols of allegoric women, representing virtues and heraldry, mounted in symmetrical layouts. The women displayed were often painter models, posing for these banknote designs. The emergence of the nation state is another development these days. Design elements were added contributing to experience the nation's identity (UXF 1), such as coats of arms, heraldic beasts or other national symbols, like motifs relating to folklore.

Confidence in the economy was challenged in the 1920s. The poor position of the economy influenced the designs created within the period of *Small portraits*, a period in which central banks disconnected one-after-the-other the convertibility of their banknotes to silver or gold. People lost trust in their currencies due to hyperinflation and depression. Confidence should be recovered - aiming for UXF 3 - by introducing portraits of (modest) persons whom people trusted. The text 'pays to bearer' was printed more prominently on the front of the banknotes, another measure to increase confidence.
The convention of Bretton Woods (1944) triggered a new era of banknote designs, with the proposed name *Great men*. The US dollar was the only remaining currency being convertible to gold; others, mainly Western currencies, were tied to the dollar. The text 'to pay to bearer' disappeared from banknotes. To support confidence, portrait sizes were increased. The persons depicted were male, selected from the forebears of the national civilization, like artists and scientists. Furthermore, the issuance of a consistent series designs underlined that the central bank is in control of the currency (UXF 3).
Next to portraits, new printing techniques were introduced, like complex line printing in alternating colours (UIF 3).
In 1971, the United States unilaterally terminated the Bretton Woods system, which was the start of the design period of *Great men and women.* The dollar became a free-floating currency. Dollars were no longer linked to gold, but foreign currencies kept a fixed exchange rate to the US dollar. This last tie was released in 1974 and all currencies became free-floating. From then on, trust in banknotes is solely based on the value of the currency and the genuineness of the banknotes (UIF 3). Although a major event, the introduction of 'banknotes as just a piece of paper' did not leave any trace on the design of the banknotes.
The last period, *Nature and buildings,* is running parallel to the period of Great men and women. In 1981, a portrait on a Dutch banknote was replaced by a bird (UXF 4). This event is taken as the start

of a new design period, as since then portraits have been progressively replaced, especially after the issuance of the euro in 2002. Banknote designs, however, have such a large variety, that there were already banknotes with flora and fauna before 1981. In Algeria, for example, birds are displayed on the 10,000 franc and the 5,000 franc, issued in respectively 1956 and 1958. Figure 4.4a shows an example of zebra's on a banknote issued in Rwanda in 1978.
Banknotes issued within this period of Nature and building are not only connected by their themes, it is also their lay-out, as illustrated by figure 1.12. Modern banknote designs are reflections of the designs made in the 1980s when cash was king.

CLASSIFICATION OF BANKNOTE DESIGN PERIODS	
Period	**Name**
1. Pre 1850	Early banknotes
2. 1850 - 1923	Prosperity
3. 1923 - 1944	Small portraits
4. 1944 - 1971	Great men
5. 1971 - to date	Great men and women
6. 1981 - to date	Nature and buildings

Figure 1.11
Classification of banknote design periods based on Hymans (2004) and adapted by the author, including naming.

Similar underlying graphic design of banknotes

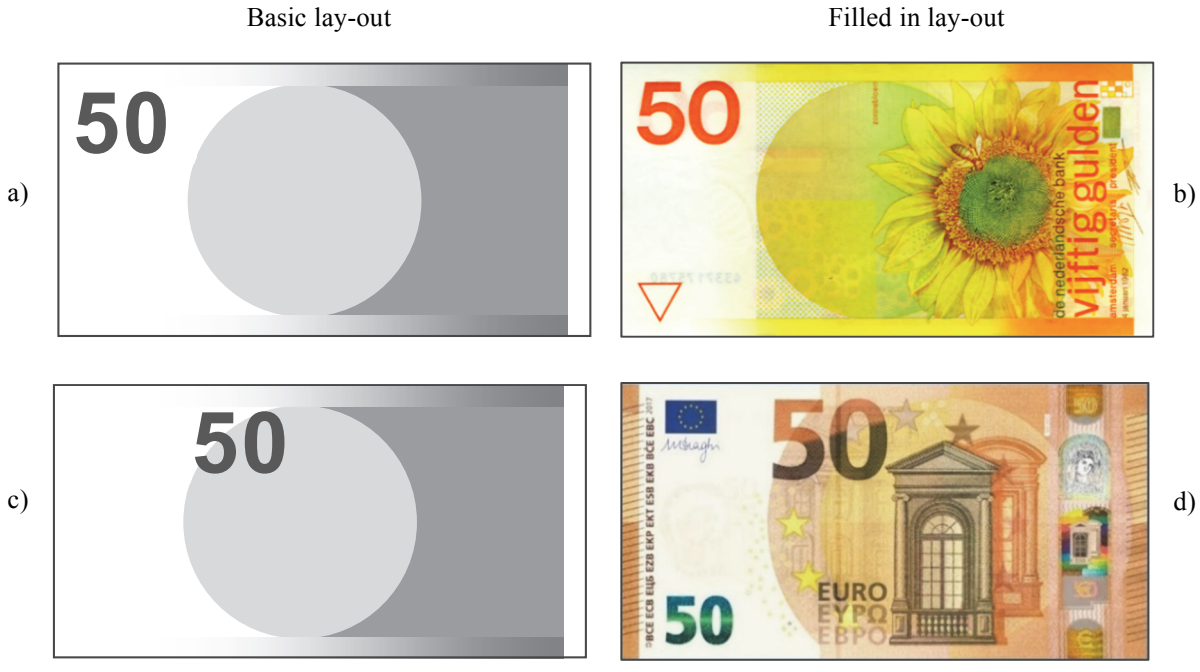


Figure 1.12
Modern designs are variants of the 1980s.
a) Basic lay-out NLG 50/Sunflower, issued in 1982.
b) NLG 50/Sunflower. Designers: Robert Oxenaar and Hans Kruit.
c) Basic lay-out EUR 50/Renaissance, to be issued in 2017.
d) Euro 50/Renaissance. Original design (1996, issued in 2002) by Robert Kalina. Re-design by Reinhold Gerstetter (born 1945).

1.3.4 Series design

Usually, a banknote design does not stand alone, but is part of a series design. A series of banknotes is more complex than a single banknote and there are three advantages identified over a solitary design. First, a consistent series design supports the public's trust in banknotes, demonstrating that the central bank is in control of both the currency's value and the currency's authenticity (Robertson, 2005). Second, the visual grammar of a series will assist the public in navigating through all denominations, while in case of solitary note designs the user must learn to operate different designs (Raymond, 2014). Third, series designs may lead to higher appreciation scores than in the case of solitary designs as reported for former Dutch gulden banknotes (De Heij, 2002).

Any graphic series, like postal stamps, coins or banknotes, can be defined by the number of components (c) that make up the series. These components of a series S can be identified by S_a , S_b , …S_i , …S_n . The lower limit for a series is set at 2 and the upper limit seems to be 8, as there are no contemporary banknote series composed of 9 or more denominations (De Heij, 2012). Payne and Morgan (1981) reported that the average number of components of a series of banknotes is 6.
A small series, consisting of 2 or 3 components, may give the impression of being less prosperous, while a series with $c > 8$ suggest inefficiencies and could be perceived as anticipating on inflation. This brings the conclusion that a banknotes series of c denominations appears to have a lower and upper limit: $2 \leq c \leq 8$.
This thesis advocates for a series of four denomination ($c = 4$), three ATM-denominations and one saving denomination (subsection 3.2.1).

Two basic concepts are identified to prepare a series design, a *series design* and a *se-tenant series design* (De Heij, 2012). Most common is a series design, characterised by sibling designs being similar in their underlying design layout. A se-tenant series is a term borrowed from philately, where it is used for stamps of different designs, joined together side by side. Se-tenant is French for 'holding together'.
Examples of se-tenant designs are provided in figure 1.13, respectively for a series of coins and a series of banknotes. Like the pieces of a puzzle, the components are graphically connected to one image.

Se-tenant series designs

a) b)

Figure 1.13
Examples of se-tenant series designs.
a) Placed together these British pound coins make up a shield of The Royal Coat of Arms of the United Kingdom, issued in 2009 (design by Matthew Dent).
b) Series design based on the Statue of Liberty within the US dollar Redesign Project, published in 2009 (design by Michael Ross).

1.4 Research questions

This thesis provides answers to the following research questions:

1. Is it possible to develop a Model for Use-centered Design of Payment Instruments, the Upid-Model, which can be applied to banknote design?

2. Does the Upid-Model deliver an appropriate framework to report measurements reflecting the users' perspective?

3. Is the Upid-Model an appropriate model to underpin the design of a new banknote?

4. Can the Upid-Model also be applied to digital payment instruments?

1.5 Outline

Banknote design is a niche area of product design. This thesis proposes a *Model for Use-centered Design of Payment Instruments*, in short the *Upid-Model*, connecting banknote design with two existing knowledge domains, respectively *Economy* and *Design Methodology*. The *economic functions of money* are converted into the *user functions of a banknote*. User functions are divided into functions serving the *use* of a banknote and functions serving the *experience* of a banknote, showing similarity to the domain of *Interaction Design*.

The banknote user is not put in front of modern banknote design, a process driven by graphic production techniques. These techniques should be quite different from commercially available reproduction techniques. Since the 1970s, the number of authenticity features increased because of the emergence of automatic banknote inspection, while on the other hand banknote sizes were decreasing because of public preferences. These two developments make that a technology-driven design policy dominates over a use-centered design policy.

Chapter 2 presents the theoretical framework developed, the Model for Use-centered Design of Payment Instruments. It starts with the *Economic Functions of Money* as defined by Jevons (1875). Modern payment instruments, including banknotes, have three economic functions. The most relevant to the daily use of payment instruments is a means of payment, the other functions are a unit of account and hoarding.
The developed Upid-Model connects two existing domains of product design, respectively *Use-centered Design* and *Interaction Design*. The focus of Interaction Design is on the design of images on computer screens, which shows similarities to banknote design. Just like banknotes, screen design is a matter of 2D-design and interacts with its user. Interaction design is divided in *User Interface Design* and *User Experience Design*. Similar, the Upid-Model divides the user functions of a banknote in User Interface Functions (UIFs) and User Experience Functions (UXFs).

Chapter 3 reports in detail on four User Interface Functions (UIFs). The most decisive user function is 'recognising value' (UIF 1); the others are: 'handling' (UIF 2), 'checking authenticity' (UIF 3) and 'receiving a communication message' (UIF 4).
The main conclusion is that modern banknotes show shortcomings on all these four user functions. Suboptimal designs are also delivered to the visually impaired.

Chapter 4 reports in detail on six User Experience Functions. The most decisive user function is 'experiencing identity' (UXF 1). The others are: 'judging aesthetics' (UXF 2), 'keeping confidence' (UXF 3), 'reacting on the main image' (UXF 4), 'requiring sustainability' (UXF 5) and 'linking to information technology' (UXF 6).
User Experience Functions are not strictly required to make a payment. From an historical point of view most UXFs have been added after the introduction of the User Interface Functions. One of the

observations is that modern banknotes tend to focus on UXFs, while for a daily payment the UIFs are more relevant.
Obvious design variables are identified for the UIFs, while the design variables of UXFs seem to be more multifaceted.
Concluding, the number of User Experience Functions of banknotes are increasing; new UXFs are identified like requiring sustainability (UXF 5) and linking to information technology (UXF 6).

Chapter 5 is a review on user behaviour with banknotes. Obviously, such knowledge is essential for a use-centered design approach. An overview is provided of the knowledge on perception of banknotes and includes several contributions. The most important is the *4M Model for the Perception of Banknotes,* a model providing insight in people's attention for banknotes. One more novelty is the *Model for the New/Upgrade Ratio of Banknote Design,* using two parameters to create a concept for a new banknote: technical innovations and graphic design.

Chapter 6 presents the measurements done on the user functions of banknotes covering the period 1981-2017, for both Netherlands gulden and euro designs. Measurements are reported for four different types of banknote designs, two variants of Dutch gulden and two types of euro design. Measurements on gulden banknotes concern the "House-Tree-Animal Series" (NLG, first issue 1965) and the "Abstract Series" (NLG, first issue 1989). Measurements on euro banknotes concern the "Ages and Styles of Europe" (Euro Series 1, 2002) and the "Europa Series" (Euro Series 2, first issue in 2013).
Measurements are reported as longitudinal measurements and single examinations. Supporting measurements on user functions of other currencies are limited and are reported when available.

Chapter 7 demonstrates how a banknote design concept is created along the lines of a Model for Use-centered Design of Payment Instruments. With the help of the *Method for Creating a Usage Layout for Banknote Design* a conceptual design for series of MAX-banknotes is developed, an imaginary currency representing Money from Area X.

Chapter 8 starts with an analysis of cash from a users' perspective. General user criteria are provided for any means of payment and pros and cons are reported for banknotes. The question arised whether the Upid-Model is applicable to digital payment instruments. After investigating this question for a debit card and a wallet app on a smart phone, the answer turned out to be positive. This is the reason to present the developed Model as a Model for Use-centered Design of Payment Instruments. Furthermore, the question is answered whether the presented design advices for banknotes are also relevant for the design of digital payment instruments.

Chapter 9 is the final chapter and offers conclusions, discussions and recommendations. The four research questions received all a positive answer.
First, a Model for Use-centered Design of Payment Instruments is developed. This Model proves to be a realistic representation of the use of the payment instrument subject of this thesis, a banknote. The Model is summarised in a relatively simple table, presenting four User Interface Functions and six User Experience Functions. The Upid-Model also includes the description of user requirements for each user function of the Model. When these user requirements would be applied in future banknote designs, these designs are expected to reach higher usability and experience scores than the banknote models they will replace.
Second, the Upid-Model delivers an appropriate framework to report on measurements reflecting the users' perspective. Measurement methods are available, or can be developed, to assess each of the defined user functions. Different banknote designs can be compared to each other, using the scores of each single user function. The measurements on 'judging aesthetics' (UXF 2) discriminate between the design qualities of different gulden and euro designs.
Third, the Upid-Model is an appropriate model to underpin the design of a new banknote. For each user function, an optimal design concept can be created, called a *usage layout*. When user functions are ranked on their user relevance, these different design solutions can be brought into a generic template for a series design. Application of the Model leads to a novel type of banknote design.

One size fits all.
General expression

CHAPTER 2
MODEL BUILDING ON USE-CENTERED DESIGN OF PAYMENT INSTRUMENTS

2.1 Introduction

Use-centered Design is a specific form of *design*. Dictionaries provide several meanings of design, ranging from conceiving a plan in the mind to making a drawing or pattern of something to be made or built. As a banknote is a product, design is limited to the *design of material products*, for which purpose Roozenburg and Eekels (1995) defined design as follows:

> "Design is to conceive the idea for some artefact or system and/or to express the idea in an embodiable form."

The product to be designed can be approached in different ways, expressed by the *design policy*, which may range from specific problem solving to a holistic approach, respectively from a new banknote design to an alternative means of payment.
Arguments of the designer to fill in the design are the *design philosophy*. Two opposite design policies are discussed in this chapter, respectively a *technology-driven design policy* and a *use-centered design policy*. The balance often tips towards a technology-driven design policy, illustrated by a definition of banknote design by the Reserve Bank of New Zealand (2016):

> "Banknote design requires very specific technical knowledge in a range of areas, including aesthetics, printing techniques, security features and banknote equipment requirements."

A use-centered design policy puts the end user in front. Use-centered design policies for banknotes are underdeveloped and this chapter makes a start with model building, connecting two knowledge domains: *Use-centered Design* and *Interaction Design*, the latter concerns the design of images on computer screens.

The first question regarding use-centered design of banknotes is: Who are the users of banknotes? This question is usually answered by a classification of authenticity features, namely *Level 1* (public), *Level 2* (retailers) and *Level 3* (central banks) as will be elaborated on in subsection 3.4.4. However, checking banknotes on authenticity is not why people use banknotes. A common *usage situation* is 'value recognition'. Looking for the value, people are in *denomination mode*, one of the *User Function Modes*, a novel term, combining the user and the user function, which will be introduced in more detail in section 2.7. Another user function mode is the *handling mode*, describing the situation that people store a banknote in their wallet. People may switch from one user function mode to another. A just received banknote can be dirty, damaged or may provide a blurred impression. In such a case, people may leave the denomination mode and opt for the *confidence mode* as they will make up their mind whether they can trust the deviant, just received banknote. When distrust persists, they may switch to *authenticity mode* and may perform an *authenticity self-check*.

Literature does not provide a model for banknote design. Banknotes are part of the domain of graphic design. Graphic design and user-centered design are connected in "User-Centered Graphic Design" (Frascara et al., 1997). However, the design methods presented are not applicable to banknote design, as the focus is on visual communication design beyond its usual commercial applications, like for example communication on traffic safety.

The well-known publication “Design of Everyday Things” delivered inspiration, but does not deliver a model either (Norman, 2013; 1988). A first publication on user-centered design related to banknotes is the development of a reading device for blind people, which is also able to denominate a banknote (Peters et al., 2004). This study highlights how human aspects should be managed within an engineering space.
The subtitle of a recent publication on design is “Why designing a chair is the same thing as designing a website” (Oosterlaken, 2017). Although job titles of designers may be different, like graphic designers, interaction designers and UX/UI designer, their design processes overlap. This article supports the idea that the banknote designer can be compared with a website designer, as “chair” can replaced by “banknote”.

The method applied departs from the three economic functions of money: unit of account (1), means of payment (2) and store of value (3). These economic functions are transferred into the user functions of a banknote. Key is the discrimination between *use* and *experience*; user functions are divided into User Interface Functions (UIFs) and User Experience Functions (UXFs).
The main result is the Model for Use-centered Design of Payment Instruments, serving the design of user-friendly banknotes.
Ten user functions are identified within the Model for Use-centered Design of Payment Instruments, four User Interface Functions and six User Experience Functions.

Model building starts with design methodology, linking the design of banknotes to the domains of use-centered design and interaction design (section 2.2). Subsequently, four basic models on banknote design are introduced (section 2.3). User functions of banknotes are derived from the economic functions of money, another link to an existing knowledge domain (section 2.4). Subsequently, the economic functions of money are converted to the user functions of banknotes, divided in User Interface Functions (UIFs) and User Experience Functions (UXFs). The following topic is the Model for Use-centered Design of Payment Instruments (section 2.5). The main user group is the public, but there are also others (section 2.6). User function modes identify which user function is used by which user (section 2.7). People may find one user function more important than another, a matter of ranking UIFs and UXFs (section 2.8). The Upid-Model also clarifies how to arrive from user functions to design requirements (section 2.9). Three situations of public engagement are introduced, the most relevant is the *Model for User Feedback on Banknotes* (section 2.10), before ending with conclusions (section 2.11).

2.2 Linking the model to existing knowledge domains

The Upid-Model connects two fields of knowledge within the domain of design methodology, respectively Use-centered Design and Interaction Design. Use-centered Design is derived from User-centered Design, with an r in User, a knowledge domain developed within the last 25 years. Interaction Design is younger, known for about 20 years.

2.2.1 Development of Use-centered Design

Publications on product design usually concern *consumer products*. A banknote is not a consumer product, but a *utility product,* like a public bus or a letterbox. As banknotes include *services*, they are also a *commodity*, like the provision of clean and authentic banknotes. Similarly, a public bus includes the service of transportation and a letterbox includes the delivery of the posted pieces. A banknote is a special utility product, because of its high proximity to the user; banknotes may even take the body’s temperature like a seat in public transport (De Heij, 2012). In general, people will have more interest in consumer products than in utility products, as they have a free choice in case of consumer products. Within the category utility products, people may have a higher interest in a banknote than in a letter box or a street lamppost, because of its nearness.
Unlike consumer products*,* utility products are designed by public organisations on behalf of their users.

In literature on product design a shift can be observed from the consumer to the user. Already in the mid-1940s studies were published on the fit of technology and *human behaviour*. A well-known example is "Human Factors Engineering" (McCormick, 1964).
In 1984, Dieter Rams (born 1932), a well-known industrial designer, formulated "Ten Principles for Good Design" (Vitsoe, 2012), giving the users a central place in the design process. One of these principles is "Good Design Makes a Product Useful".

The first to introduce the adage *designing for usability* seemed to be Gould and Lewis (1985), focussing on three basic principles: an early focus on users and tasks (1), empirical measurements (2) and an iterative design (3). In 1995, Nielsen published "10 Usability Heuristics for User Interface Design", emphasing an intuitive use of the information displayed on computer screens. Earlier, in 1988, Norman introduced the term *User-centered Design*, a design policy characterised by an early and continual focus on people using the product. When Norman came to this insight, it was the time that electronic devices, such as a video recorder, were delivered with thick manuals on how to operate it. According to Norman, existing terms like *human interface* and *usability* did not cover the wider understanding of people interacting with computer products, including such issues as usefulness, desirability, credibility and accessibility. Norman worked several years for the Apple Computer Incorporation, where foreman Steve Jobs (1955-2011) became known for his quote that "User experience is the only thing that matters" (Isaacson, 2011). Jobs turned Ford's statement on black cars by 180 degrees (full statement cited in section 1.1).
Norman's publication was a prelude to the many publications which appeared on the phenomenon of User-centered Design, like, *Customer-centered Design* (Beyer and Holtzblatt, 1998) and *People-centered Design* (Frascara, 2002). Instead of 'centered', common in the US, older publications may use 'centred', the English version. Both versions have the same meaning and in this thesis, centered is applied. Even more variants are created, as "centered" can be replaced by "centric", like a "User-centric Approach" (De Bont et al., 2013).
In 1999, the first ISO-norm was published under the heading *Human-centred Design* and a revision appeared in 2010 (ISO, 2010a).
The term *Public-centered Design* is suggested in subsection 1.3.1 as being appropriate in the case banknotes, a term which could not be retrieved.
A related term to User-centered Design is *Intuitive Design* (e.g. Spool, 2005). Intuitive design aims for product usage without learning or training. Intuitive design bridges the gap between current knowledge and target knowledge. A synonym for intuitive design is self-explaining design.
Another contribution came from the perspective of product quality (Vredenburg et al., 2002). Once the design is ready, the quality of the product design should be assessed by its future users.
Related to User-centered Design is the development of *Agile Design*. Agile means 'lots of moving' and the term agile in relation to design was first coined by Beck et al. (2001). An agile design approach is characterised by a short cyclic design process, delivering at each cycle information, including information on customer input (Ratcliffe and McNeill, 2012).

In case of utility products, such as banknotes, it is more appropriate to focus on the *use* or *usage*. The step from *user* to *use* is made by Flach and Dominguez (1995), when they introduced the term *Use-centered Design*. Use-centered design focusses on skill performance in specific work or problem domains, in case paying each other with banknotes. Where User-centered Design focusses on the needs, wants and limitations of the end-user of the product, Use-centered Design aims for learning by experience, coupling perception and action.

Further understanding of the domains of User- and Use-centered Design is brought by distinguishing the context of a *design approach*, which can either be (De Bont et al., 2013):

1) User-centric Approach (user + product),
2) Organisation-centric Approach (user + product + organisation),
3) Society-centric Approach (user + product + organisation + society).

The first approach, a *User-centric Approach*, reflects the interaction of the user with the product, like a Use-centered Design as introduced in this thesis.
The implications of the other two approaches are reaching further than just a new banknote design. The introduction of the euro banknotes in 2002 was a project aiming for an *Organisation-centric Approach,* as the main aim of the Eurosystem was to design banknotes that all members would agree upon.
A *Society-centric Approach* aims for a payment system with the lowest social costs (subsection 8.2.3). Instead of a new banknote design the outcome of such an approach could be a completely new infrastructure servicing one or more digital payment systems, for example based on block chain technology.

2.2.2 Design terminology borrowed from Information Technology

Further inspiration for model building on Use-centered Design of banknotes is found in the images on computer screens. Like a banknote, the information presented on computer screens is a form of *graphic design* or 2D-design, while *industrial design* represents 3D-design. The first images on computer screens appeared in the 1970s, which brought the first terms for such images within the domain of *Information Technology*.
At first the designers of these images were graphic designers, but within a few decades it became a discipline on its own, known as *Interaction Design*, a term credited to Moggridge (2007). Screen designs are roughly split in screen designs for consumers (e.g. websites, games, apps) and for professionals (e.g. medical, engineering and administrative).

The term *User Interface* appeared for the first time at the end of the 1970s in the domain of computer technology (e.g. Helmke, 1979). User Interface is probably derived from *Man-Computer Interface*, coined by Stewart (2008). Stewart saved a clarifying drawing which he made in 1976, a human body and mind interacting with a computer (figure 2.1). When the computer is replaced in this drawing by a banknote, the *Man-Banknote Interface* is delivered, a relevant term, as like a computer, a banknote interacts with the body and the mind. In the 1980s, human-computer interaction remained a topic, delivering new terms like *Interface Design* (Shneiderman, 1987).

User Interface and Interface Design merged into *User Interface Design* (UID), as published by Nielson (1995), already referred to in subsection 2.2.1. An example of this type of design is provided in figure 2.2a, a working interface, but to most users at first a puzzle. Opposed to such type of designs is the screen design shown in figure 2.2b, which will be quickly understood by the user of this gasoline station, an example of *User Experience Design* (UXD). Predictability and simplicity are for a screen designer typical user experience functions. For example, a visualised path keeps track of the search actions carried out, or an on-going time bar indicates how much time is left before the video is finished. Furthermore, popups should appear in a logical sequence and by blinking they attract attention.
Garret (2002) introduced the User Experience Design, next to the already known term of User Interface Design. Garret also proposed their abbreviations, respectively UID and UXD. Both terms became well-known in academic literature on product development (e.g. Van Kuijk, 2010). Nowadays one may find for both type of designer's job advertisements like respectively 'Asked: world-class UI Designer' and 'Searched: UX Designer'.

Summarising, a User-centered Design approach is commonly applied for consumer products. A banknote design can be compared with the design of images on a computer screen, known as Interaction Design, split in User Interface Design and User Experience Design. The two terms, *use* and *experience*, are a relevant starting point for the development of a Model for Use-centered Design of Payment Instruments.

The man-computer interface

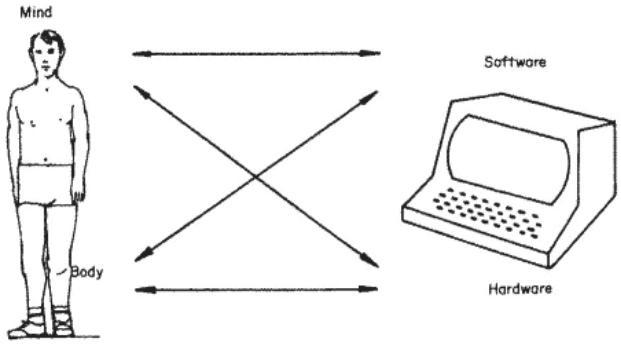
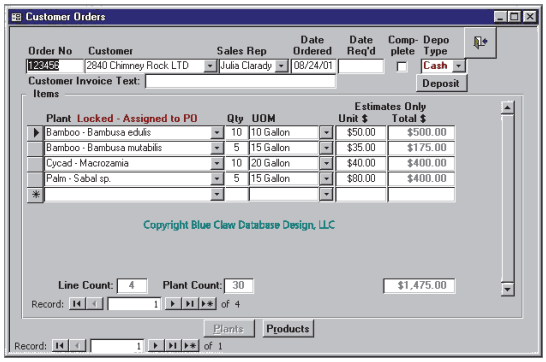


Figure 7.1. The man–computer interface.

Figure 2.1
Drawing of the man-computer interface (Stewart, 2008; 1976). Each arrow represented a set of physical issues (body) and cognitive levels (mind).

Interaction Design

User Interface Design



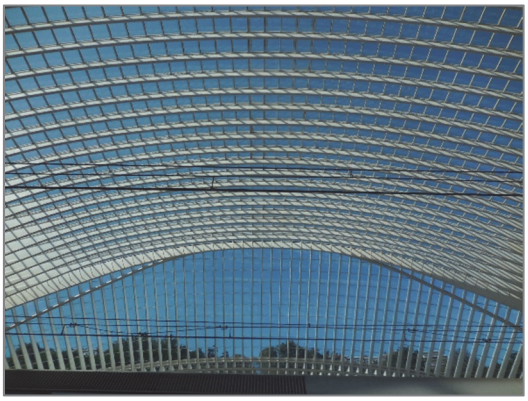
a)

User Experience Design

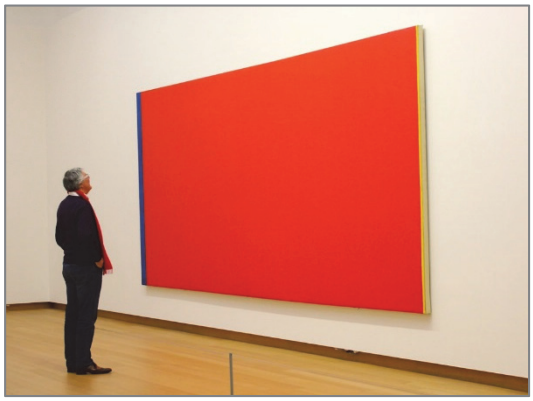
b)

Figure 2.2
Interaction Design (ID) is divided in User Interface Design (UID) and User Experience Design (UXD).
a) Example of User Interface Design. Everything works, but it is not easy to comprehend. Image: public domain.
b) Example of User Experience Design. It is immediately clear which button should be pushed to confirm an order of 50 gallons of gasoline. Image: public domain.

Use and Experience



a)



b)

Figure 2.3
Architects and Artists speak about “Use and Experience”.
a) Architect: Santiago Calatrava (born 1951). Railroad station in Luik, 2009. Image: De Heij, 2016.
b) Painter: Barnett Newman. Who’s Afraid of Red, Yellow and Blue III, 1967. Image: public domain.

2.3 Combining use and experience brings four design models

The terms use and experience are not only encountered within the domain of User Interaction Design. Architects and artists often distinguish between use and experience when they explain their designs. The use of a building will receive more weight than its experience, at least in general (figure 2.3a). In case of a painting it will be the reverse, the experience will be key, as the use of a painting is bluntly 'something for on the wall' (figure 2.3b). An explanatory example from another field concerns the preservation of open waters in the Netherlands. Like banknotes, open waters are a commodity. The use of open waters can be defined by swimming, sailing, fishing, diving and skating, while its experience can be defined by walking close to the waterfront and looking at eco-friendly banks (Stichting Toegepast Onderzoek Waterbeheer, 2014).In the 1990s the term *experience* received a boost, when Pine and Gilmore (1999) introduced the "Experience Economy", offering emotional value to a product or service by introducing the 4E's, respectively Entertainment (1), Educational (2), Esthetic (3) and Escapist (4). The attention for experience was also noticed by product designers, as customers would no longer take a functional product as a given, described as a "clear shift from object-centered to experience centered design" (Buxton, 2007). This trend is also reflected in the titles of publications like "Emotional Design" (Norman, 2005), "Product Experience" (Schiffers and Hekkert, 2008) and "Happy Design" (Pavliscak, 2015). Creating a little smile is a common objective of use-centered design policy (Jordan, 2000); indeed, people may respond positively when a banknote elicits a little smile, which may lead to attention for the banknote.

Application of the variables use and experience leads to four basic models to approach a new banknote design as shown in figure 2.4.
As a new banknote design will replace an existing one, the novelties of a new banknote should be compared to its predecessor. If not much has changed - neither in use, nor in experience - the design is an *upgrade* (Model 1). The replacement of the first series of euro banknotes, starting in 2013, is an example of this category (figure 2.5a), as the second series kept the design close to the first (De Heij, 2013a).
The replacement of paper-based banknotes by synthetic substrates is an example of Model 2, since the new use of the bank notes is emphasised. The graphic designs are usually kept, as in case of the transition of the Canadian banknotes to polymer (figure 2.5b). Since the first Australian polymer banknote was issued in 1988 (figure 5.25), over 35 central banks issued their banknotes printed on this synthetic substrate instead of a paper based one, including New Zealand (in 1999) and the United Kingdom (in 2016).
Model 3 represents new banknote designs which introduce new graphic designs, emphasising the user experience. The new series of Swedish banknotes is an example of this category. Historic portraits are replaced by images with more public appeal, like persons known from the cinema (figure 2.5c).
The introduction of the euro in 2002 is an example of Model 4, new banknote designs emphasising both the use and the experience. The introduction of a new currency was a break of the use and the experience, as the national currency was replaced by the euro and portraits by buildings. A more recent example is the Norwegian banknote series "The Sea" (figure 2.5d). This series introduces main images from different *image categories*, like an animal (fish) and a building (lighthouse), which supports instant value recognition, the main user function. Furthermore, the Norwegians underlined their banknote identity, the main experience function.

BASIC MODELS OF USE AND EXPERIENCE OF BANKNOTE DESIGN		
Model	**User Functions**	
	Use	Experience
1. Customise existing design (upgrade)	o	o
2. Emphasise use	●	o
3. Emphasise experience	o	●
4. Emphasise use and experience	●	●

o = Maintained design policy

● = Result of new design policy

Figure 2.4
Four basic models to approach new banknote design.
Compared to the existing banknote model a new banknote design may have different settings to emphasise the use and/or experience aspects.

Basic Models of Banknote Design, examples

Figure 2.5
Four examples of basic models to approach a new banknote design.

2.4 Economic functions of money

Banknotes are a means of payment, serving one of the economic functions of money as first analysed by Willian Stanley Jevons (1835-1882). In 1875 Jevons unveiled four economic functions of money: medium of exchange (1), common measure of value or unit of account (2), standard of value or standard of deferred payment (3) and store of value (4). Since 1974, money is no longer linked at a fixed rate to gold or to any other currency convertible to gold (subsection 1.3.3). The economic function of a standard value has been taken over by world currencies like the US dollar and the euro, which are accepted standards for international settlements.
Modern banknote designers do not seem to follow Jevons' economic functions of money, as within a series of banknotes no difference is made between the design of denominations meant for daily payments and the design of high values, used for payments and saving. For example, within the euro series the design layouts of the euro 5 and the euro 500 are similar, except for the size and two additional public authenticity features on the euro 500.
Three of the economic functions of money are still relevant to date and are introduced as follows: a unit of account (subsection 2.4.1), a means of payment (subsection 2.4.2) and a store of value (subsection 2.4.3).

2.4.1 Unit of account

The dimension of a currency is the unit of account. This unit can be anything people agree upon; it can be one working hour or a currency unit like *euro*. An early example is the *cod*, which was the unit of account in the trade between England and Iceland in the 14th century. The cod was used to compare prices; people did not really pay each other with cods. An original price list informs that the price of 48 yards of textile was 120 pieces of cod (Van Erve, 1998; Van Renselaar, 2002).
The unit of account makes it easy to compare prices, known as *price transparency*. When people are in a foreign currency zone, they must convert their currency into the local one. Furthermore, transaction costs will be charged.

A relevant design parameter of a banknote is the name of the currency. Early *currency names* were derived from precious metals like gold (e.g. *gulden* and *zloty*) or silver (e.g. *rupiah* and *sterling*; sterling indicates 92.5% silver). *Peso* and *mark* are currency names associated with weight, while *yen* refers to a circular shape. Currency names of later date were associated with symbols, like a shield (*escudo*), kingdom (*crown*) or lion (e.g. *lev* and *leu*), followed by currencies named after national heroes, like the *colón* in Costa Rica, named after Cristóbal Colón or Christopher Columbus (1451-1506) and the *boliviano* in Bolivia named after Simon Bolivar (1783-1830). A town, country or region may also be the origin of the name of a currency unit, like the *afghani*, referring to Afghanistan, the South African *rand* referring to the gold vein in Witwatersrand, the *leone*, referring to Sierra Leone and the *euro*, referring to Europe.
When currencies have similar names, this can be confusing. *Dollar* is part of the name of several currencies, like the Australian dollar, Hong Kong dollar, Surinamese dollar and United States dollar. Similarly, the *peso* is used in Mexico, the Philippines and some other nations. In international trade, such names are confusing and therefore the International Organization for Standardization (ISO) introduced in 1978 three letter alphabetic codes for the representation of currencies (most recent: ISO, 2008a). Examples are USD for US dollar and CAD for the Canadian dollar. The currency code XEU was reserved for the European Currency Unit (ECU or *ecu*) and is, like the cod, an example of a unit of account which was never used as a means of payment. At the time of the decision to introduce the euro, in 1992, the currency's name ECU was found no longer appropriate and with "euro" a symbolic currency name has been selected in 1995 and its introduction followed in 1999. The change from ecu to euro was at parity: 1 euro = 1 ecu and the currency code of the euro became EUR. The introduction of the euro coins and banknotes followed in 2002.
Although standardised, ISO currency codes are, as far as known, not printed on banknotes, except for the code NLG on the NLG 10 issued in 1997 (figure 1.2a).

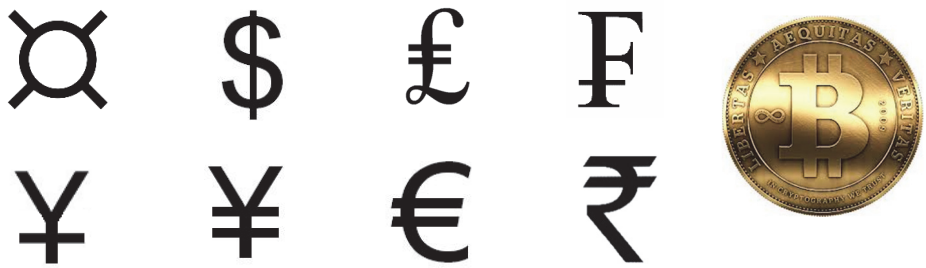
Once a currency has a name, a currency symbol may be developed. An impression of the development of currency symbols is provided in figure 2.6 (De Heij, 2012). For the origin of the currency symbol of the dollar (figure 2.6b) several explanations are available. The most common is the one telling that the symbol is the evolutionary result of the abbreviation of the Spanish piaster to PS. The currency symbol for the British Pound (£) is the letter L, derived from the Latin word 'libra', meaning pound (figure 2.6c). Libra was the basic unit of weight in the Roman Empire, which in turn is derived from the Latin name for balance. Originally one pound represented a value of about 334 grams of pure silver. Although the Bitcoin is a virtual currency, there are fabricated images of a Bitcoin, as shown in figure 2.6i. Like in many currency symbols, the symbol for the Bitcoin uses two parallel lines, which symbolise stability.

Currency units are usually *national currencies*. There are also other types, like *supra-national currencies* such as the euro. The US dollar and the euro are often referred to as *world currencies*, as their use is worldwide. Furthermore, there are *global currencies, regional currencies, virtual currencies* and *crypto currencies*.
The development of the internet made it possible to launch virtual currencie*s,* currencies without a nation and beyond control of any authority. Virtual currencies may have an exchange rate with currencies in the real world, as was the case with the *Linden Dollar*, launched in 2003 as part of Second Life, an electronic game available on the internet, where virtual personalities (avatars) used this currency to pay with.
In 2009, a new type of virtual currencies appeared, named Bitcoin, with the currency code BTC (Nakamoto, 2008). Such virtual currencies are based on distributed ledger technology, supported by public input and are therefore also referred to as crypto currencies. After the Bitcoin, several of such currencies were introduced, like Monero (in 2014, currency code XMR), Dash (in 2014 released as XCoin and in 2015 renamed to Dash, currency code DSH) and Euthereum (in 2015, currency code ETH).

A development contrary to global currencies are *regional currencies* (De Heij, 2012 and the references therein; Naqvi and Southgate, 2013). Regional currencies are known since the 19th century, but since the 2000s, modern variants of regional banknotes were introduced in Europe and the USA, characterised as *protest currencies*, local money meant to diminish the effects of large scale currencies. These banknotes can only be spent in the region, supporting the local economy. A regional currency may use coins and/or paper money - popularly banknotes - as payment instruments and may also be an electronic payment systemIn the past, economists have also been critical on the social effects money may have. According to Karl Marx (1818-1883) money is a radical leveller that does away with all distinctions of traditional social relations (Marx, 1887). Georg Simmel (1858-1918) followed up on Marx' critique, focussing even more sharply on money itself (Simmel, 1900). According to Simmel, the quantitative logic of asking 'how much', repainted the world into an evenly flat and grey tone, making the world colourless.
The designs of the regional paper money focus on alternative communication functions, while their design concepts stay quite close to the banknotes of the criticised currencies (figure 2.7).

Currency symbols

a) b) c) d)



e) f) g) h) i)

Figure 2.6
Variety of currency symbols, in order of their appearance (Images: public domain).
a) Oldest currency symbol, East Asia. Date unknown.
b) US dollar (USD), before 1785.
c) British Pound (GBP), around 1800.
d) French Franc (FFR), around 1800.
e) Chinese Yuan (CNY), before 1871.
f) Japanese Yen (JPY), before 1871.
g) Euro (EUR), 1974/1997.
h) Indian Rupee (IDR), 2010.
i) Bitcoin (BTC), 2009. Although the Bitcoin is a virtual currency, there are several fabricated images of a Bitcoin.

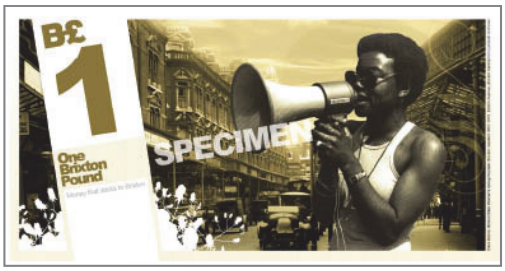
Regional currencies

Raam, Netherlands, 2001 Rheingold, Germany, 2007

a)

b)

c)



d)

Brixton Pound, United Kingdom, 2009 Bristol Pound, United Kingdom, 2012

Figure 2.7
Four examples of regional European currencies (Images: public domain).
a) The Maharishi movement introduced Raam banknotes in the Netherlands in 2001. The currency Raam should support the ideal of 'a country without borders for peace loving people everywhere'.
b) Banknote of 20 Rheingold, issued in the Düsseldorf region in 2007.
c) Brixton Pound, introduced in 2009. Equal to 1 GBP.
d) Bristol Pound, introduced in 2012. Equal to 1 GBP.

2.4.2 Means of payment

A payment settlement involves a *payer* and a *receiver* or the *payee.* Both are a client at a specific bank, a situation known as the "Four Corner Payment Model" (Treasury Alliance Group, 2014). Figure 2.8a describes the *Four Corner Payment Model for Cash.* Via an ATM the payer receives cash money from his bank, in the scheme Bank A. With this cash money, the payer pays the receiver, for example a retailer. Usually the payee needs change, something that retailers may receive from their bank, Bank B in the scheme. At the end of the day the retailer may bring the incoming cash money to Bank B. The Banks A and B may have settlement arrangements with each other.
The transactions described by the Four Corner Payment Model for Cash can be extended with other parties like the central bank, coin and banknote producers and Cash in Transit companies. Such models are usually referred to as the *Cash Cycle*, which will be introduced in more detail in subsection 8.2.2.
In case of digital payments on the internet a *Payment Service Provider* (PSP) takes a position in between the payer and the payee (figure 2.8b). Further elaboration on a model for digital payments is outside the scope of this thesis.

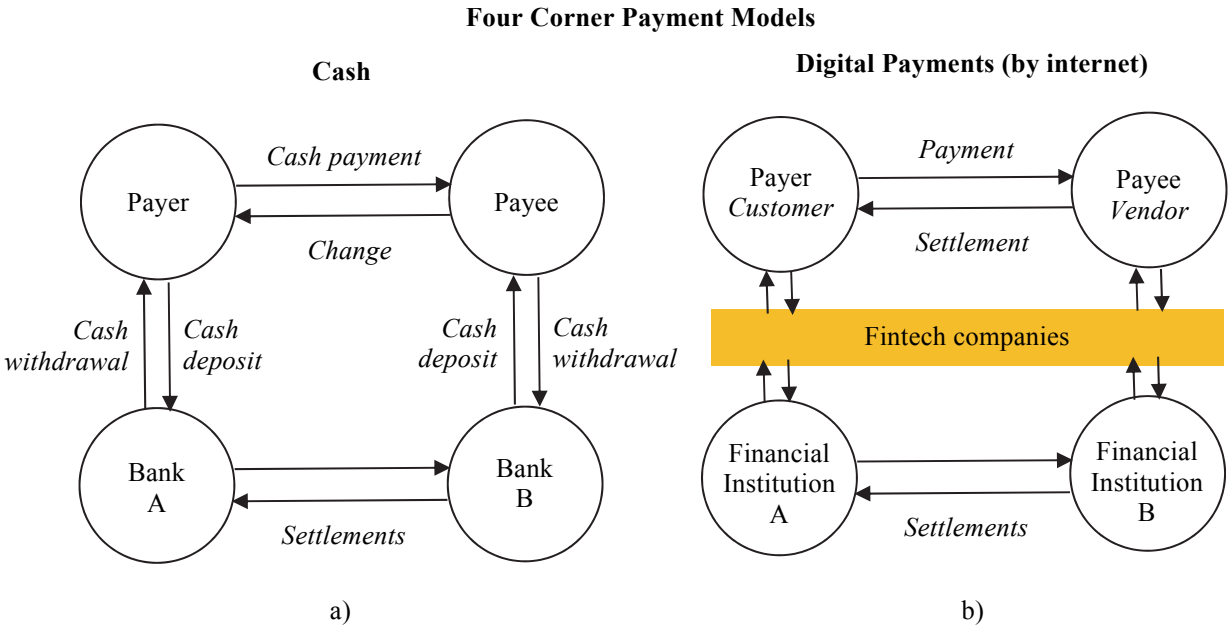


Figure 2.8
Schematic representation of two Four Corner Payment Models.
a) Four Corner Payment Model for Cash.
b) Four Corner Payment Model for Digital Payments, especially by using the internet. Fintech companies offer payment services to customers and vendors.

In the past, there was just one *payment system,* there were only coins. Next to coins, barter was popular in various parts of the world, just as commodity money like tobacco. Following the terminology introduced by Kosse (2014), within a coin payment system there is just one *payment channel* and the different coin denominations are the *payment instruments*. With the arrival of banknotes in the 17th century, a second payment channel was introduced next to coins, as illustrated in figure 2.9.
A difference between cash and digital means of payments is the number of payment instruments. For example, in case of the euro there are 15 payment instruments, 8 coin denominations and 7 different banknote values, while the user of a digital payment system operates just one payment instrument, usually a card. Indeed, according to 29 % of the Europeans there are too many euro coin denominations (European Commission, 2015).

A further drawback for cash is the interconnectedness between the two payment channels, which can be characterised as Siamese twins. When people do not like to pay with coins, they may avoid banknotes and vice versa.
The perception of coins and banknotes is not similar. It is frequently reported that coins cannot be properly distinguished from other coins as was the case in the United States, Great Britain and France (Norman, 2013). The recognition of euro coins is also troubled. According to 19 % of the Europeans, recognition and handling of euro coins is difficult, while for banknotes the combined score of these two user functions is 4 % (European Commission, 2015). Furthermore, bankcards may exist without banknotes, but not vice versa; a bankcard, which is either a credit card or a debit card, is needed to withdraw banknotes from an ATM. One more advantage of a bankcard is that one card may facilitate different types of payment instruments, like online direct debit payment transfers and online banking applications for payment of online purchases.

2.4.3 Store of value

In the past, before the era of electronic payments, there were two types of high banknote denominations, *very high* (e.g. USD 100,000 and NLG 50,000) and *high* (e.g. USD 1,000 and NLG 1,000). Very high banknote denominations were used to settle inter-bank payments; outside the walls of the banks these very high values were not used.
High denominations were used by the public, for example when they received their salary. Also houses and other costly products were to be paid in cash. Therefore, central banks offered high banknote denominations, like the NLG 1,000 in the Netherlands (in 2002 about 450 euro), the DEM 1,000 in Germany (in 2002 about 510 euro) and the CHF 1,000 in Switzerland (in 2002 about 675 euro).

High banknote denominations are no longer used to settle a cash transaction between citizens. In the Netherlands, cattle markets were in the 1990s the last places were a high denomination (NLG 1,000) was used as a means of payment. Still, the Dutch central bank continued this denomination in 1994, when a new model was designed and issued (figure 1.2d). High denominations would gradually enter the domain of daily payments, so was the argumentation. Indeed, a euro denomination of 5,000 has not been issued in 2002, which would have more-or-less an equivalent purchasing power of the NLG 1,000 issued in 1814 (De Heij, 2006a). Even more appealing is a former 1,000 pound banknote, hand written and issued in the late 17th century by the Bank of England, as today its purchasing power would be more than 100,000 euro.
The transition from a *cash society* to a *multi means of payment society* created a gap between the highest denomination in the category 'means of payment' and the high denomination in the category 'store of value'. Instead of abolishing the store of value denomination, several central banks wanted to bridge the gap between the two categories. In the Netherlands, a new denomination of NLG 250 was introduced in 1986, a denomination in between the 100 and 1,000. In Switzerland, the CHF 500 was replaced in 1997 by a denomination of 200 and the 1,000 was kept. Other central banks started with the introduction of high denominations, like in Austria were in 1988 a new high denomination was introduced of ATS 5,000 (in 2002 about 360 euro). Fifteen years later, the euro introduced three high denominations in 2002, the EUR 100, 200 and 500.

One of the first studies on the use of high denominations was done in the Netherlands (Boeschoten and Fase, 1992), reporting that a large part of the use of the 1,000 gulden banknotes could not be traced. Furthermore, they reported that this high denomination may serve tax-evasion, money laundering or payments within criminal circles. One more publication on the use of high denominations was published in 2016 (Sands, 2016).
In the Eurozone, banknotes of 500 euro became a popular denomination, accounting for about 1/3 of the total value of all euro banknotes in circulation. However, looking at the number of banknotes issued, the share of euro 500 banknotes is less than 5 % of all issued euro banknotes (situation 2015). This raised the question of who are using these high denominations. A study by the ECB reported that half of the citizens of the Eurozone have never come across a 500 euro banknote (European Central Bank, 2011). In 2012, DNB reported that only 7 % of the Dutch population used a 500 euro note and

16 % in case of the 200 (Visser and Dijkers, 2013). The 100 euro serves only marginally as a daily means of payment, used by just half the population (48 %).
High value notes are used for legitimate purposes and for unlawful actions, although it is unknown to what extent. This brings the question what central banks should do. One view is that the issuance of high denominations should be discontinued, while another view is that central banks should meet the demand. An argument in favour of high denominations is the anonymous character of banknotes and not the high value. When high denominations are not serviced, citizens - and criminals - may opt for lower denominations. One more argument is that central banks should be independent of politics and they should not adapt to considerations of law enforcement or tax offices. Meanwhile, the high denominations are facing competition from virtual currencies like the Bitcoin.

The first to abolish very high and high denominations was the US Federal Reserve System. In 1946, the FRS stopped printing very high and high denominations, including the 500 and 1,000 dollar. In 1969 President Richard Nixon (1913-1994) halted the use of all such denominations, as they would be used by organised crime, making the USD 100 the highest denomination in the USA.
In the year 2000, the Bank of Canada followed the example of the USA and ceased the issuance of CAD 1,000. This denomination retained its status of legal tender and may still occasionally serve a specific role as a price winner in game-shows on television, like "The Price is Right".
In 2016, the ECB decided to discontinue the printing of the euro 500 in 2018 (European Central Bank, 2016). The circulation on this denomination will slowly fade out. This decision came as a surprise, as at the beginning of 2016 the ECB was still working on the design of a new model for the euro 500. In the Netherlands, 76 % of the population supports this decision (Klöne and Zondervan, 2017).

MEANS OF PAYMENTS		
Payment systems	**Payment channels**	**Payment instruments**
Non-cash (electronic, digital)	Bank account	Online banking (internet)
		Debit cards
		Credit cards
		Paper forms
	Not-linked to bank account (after loading from bank account)	Pre-paid cards (chip cards)
		On-line purses (internet, smartphones)
		Virtual currencies (e.g. Bitcoin)
Cash	Coins	Coin denominations
	Banknotes	Banknote denominations

Figure 2.9
Overview of payment systems, payment channels and payment instruments.
(There are also non-digital examples of non-cash payment systems, usually at the end of their lifecycle, like cheques, coupons and tokens.)

FROM ECONOMIC FUNCTIONS TO USER FUNCTIONS		
Economic functions of money	**User functions of a banknote**	
	Use	**Experience**
Unit of account	Identify currency unit	-
	Recognise origin	-
Means of payment	Recognise value	Recognise identity
	Handle	Judge aesthetics
	Check authenticity	Retain confidence
	Receive communication message	Connect with main image
	-	Expect sustainability
	-	Link to information technology
Store of value	Access to high denominations	-
	Keep for long-term	-

Figure 2.10
From economic functions to user functions of a banknote, divided in use and experience.

2.5 Model building

The outcome of sections 2.2 and 2.3 is that user functions of a banknote can be divided in two groups, use and experience functions respectively. Section 2.4 presented the economic functions of money. Bridging the economic and the user functions is the topic of this section. Figure 2.10 presents how the economic functions of money may be converted into these two types of user functions. As the main economic function of a banknote is a means of payments, this section is the fundament of the Model for Use-centered Banknote Design.

The understanding of a *user function* needs to be defined in more detail, as this is key in a User-centered Design policy. The term user function is not explicitly mentioned in literature on design methodology. Roozenburg and Eekels (1995) specify a 'function':

> " 'Function' is a general concept. It refers to the purpose of a product, which is usually many-sided. We can therefore talk about the technical, the ergonomic, the aesthetic, the semantic, the business economic, the social and other functions of a product."

The term "user function" could also not be traced in recent literature on User-centered Design (Garret, 2002; Verhoef, 2007; Bowles and Box, 2011; Van Kuijk, 2012; Hoolhorst, 2012; De Bont et al., 2013). Norman (2013) proposed that the conceptual model of the product to be designed should be built around the users' *activity*. In other words, a function describes a product by what it should do according to the users. To fill this gap, a user function is defined here as follows:

> A user function of a product describes what the user can do with the product.

Building further on the two parameters of use and experience, a user function of a banknote is either a User Interface Function or a User Experience Function, in shorthand UXF or UIF respectively. These two abbreviations are compact and straightforward terms to indicate specific banknote's user functions, for example UIF 1 and UXF 3. Although the origin of the term User Interface Function could not be identiefied (subsection 2.2.2), the term may already have been there in the 1970s, while the term User Experience Function seems to be a novelty.

Key to the identification of the User Interface Functions is what people do with their banknotes. The most decisive user function is therefore 'recognising value' (UIF 1), as people would like to know the value of a banknote first. Searching in their wallet, people are looking for the right value. Also, when they receive a banknote as change, their first interest will be if the denomination - or denominations - at offer are correct. Subsequently, people will take the banknote or banknotes, arriving at the second usage function, named handling (UIF2). When people do not trust one or more of the banknotes at offer, they may want to do a self-check on its authenticity (UIF3). Receiving a communication message is the fourth identified usage function (UIF 4), as people may be interested in the themes, features and images displayed.
Ranking of the User Interface Functions will be further discussed in section 2.8.

Before people will use a new banknote design, a first impression is provided by User Experience Functions (UXFs). People seem to be interested in their own banknotes and not that much in banknotes from other countries. Therefore, the first UXF is assumed to be experiencing identity (UXF 1), as people will notice banknote design representing their nation. Second, within a fraction of time, people will have a judgement on the aesthetics of a new banknote design. For this reason, judging aesthetics is listed second (UXF 2). Whether the new design looks like a valuable banknote or a cheap coupon is a matter of keeping confidence (UXF 3). Furthermore, the main image of the new design is noticed instantly, is it a portrait, a bird or a tower. Reacting on the main image is therefore identified as one more user experience function (UXF 4). Two upcoming User Experience Functions are expecting sustainability (UXF 5) and linking to information technology (UXF 6). Today there is a common public interest in climate change and a 'green environment'. Therefore, the author thinks that people expect their banknotes to be 'green'. The latest function is linked to information technology. Soon after the introduction of the Eurobiljet app by DNB in 2011 (subsection 4.7.5), several users asked for an application which could scan and authenticate the banknote by itself (Van der Woude, 2016). People seem to expect that a banknote can do 'something' with information technology, like checking a banknote by using a smartphone.
Ranking of the User Experience Functions will be further discussed in section 2.8.

The Model for a Use-centered Design of Payment Instruments is presented in figure 2.11, part of the larger scheme of figure 2.10. A difference is that the user functions in figure 2.11 include a verb, they have been actively formulated.
The proposed ranking of the functions is important, as it will provide guidance to the designer. After all, there are an increasing number of features to be incorporated (subsection 3.4.3), while the banknotes' sizes are decreasing (subsection 3.3.1).

2.6 User groups

User groups and stakeholders have been introduced in subsection 1.3.1. The main (primary) user group is the public and second are the retailers; a third user group are counterfeiters (figure 2.12).
A further distinction is made for user groups using a banknote machine.
Obviously, humans observe a banknote differently than a detector. Humans read the numeral, while detectors verify the note's value by physical properties like size and spectral measurements.
Figure 2.12 also provides information on *user subgroups*. Not all subgroups are mentioned; not included are police, foreigners, collectors and journalists.
A special group of users are banknote collectors. This group is not relevant and is kept outside this thesis. Each year, the International Bank Note Society (IBNS) selects 'the banknote of the year' (IBNS, 2016).

2.7 User Function Modes

User functions are introduced in section 2.5 and user groups in section 2.6. Combined, these two parameters deliver user function modes, already introduced in section 2.1. When all user groups (*f*) and all user functions (*g*) are combined, a multidimensional space is created (figure 2.13).
The volume of the first banknotes in 1661 was already in tens of thousands, mainly used by merchants, but also by others, indicating three user groups: public (1), retailers (2) and counterfeiters (3). With the introduction of banknote machines, two different *usage situations* became relevant for each user group, like paying to another person and paying to a machine. Furthermore, the number of subgroups increased, the public, for example, is divided in normal sighted (1), colour blind (2), poor sighted (3) and blind (4), as will be elaborated on in subsection 3.2.5.
Completing the matrix of figure 2.13 for *g* user functions and *h* user groups delivers *g.h* different User Function Modes. Including the subgroups this will be even more. In case of 6 user groups and 10 user functions, there will be 60 User Function Modes. However, not all user modes are relevant for daily practice. The focus of central banks is on the 'counterfeiter' (user group) and on an 'authenticity check' (user function). Another user function mode receiving interest is 'recognising value' (user function) by the blind (user subgroup).

Subsection 1.3.1 explained that the infrastructure for using banknotes is provided by the stakeholders. Users and stakeholders meet each other when people receive a banknote from an ATM or when they insert a banknote in a payment terminal. The last decade, central banks pay much attention to the Banknote Equipment Manufacturers, the providers of such machines.
In general, people use banknotes to pay each other; people don't use banknotes to check for their authenticity. Instant recognition of its value is therefore the main user function (section 2.5). Doing so, the user is in denomination mode, in UIF 1. The most relevant user modes are marked in figure 2.14.

Analysing this table by its columns unveils that an authenticity check is the only UIF relevant to all user groups. This finding serves as an explanation for the interest of central banks to classify banknotes in accordance to their authenticity features, a topic discussed in subsection 3.4.3.
Furthermore, this table discloses that a communication message (UIF 4) is only relevant to the public at large, just like all UXFs.
Analysing this table by its rows unveils that value determination and handling are relevant to the first four user groups; each user group does have its own user requirements, as will be introduced in chapter 3.

MODEL FOR USE-CENTERED DESIGN OF PAYMENT INSTRUMENTS	
User Interface Functions **UIFs**	**User Experience Functions** **UXFs**
1. Recognising value	1. Recognising identity
2. Handling	2. Judging aesthetics
3. Checking authenticity	3. Retaining confidence
4. Receiving a communication message	4. Connecting with main image
-	5. Expecting sustainability
-	6. Linking to information technology

Figure 2.11
The proposed Model for Use-centered Design of Payment Instruments, also referred to as the Model, the Upid-Model or the Coaster Model (De Heij, 2015a).

USER GROUPS			
User group		**User subgroups**	
1. PUBLIC			
1.1	All citizens ≥ 6 years	1.1.1	Normal sighted
		1.1.2	Colour blind
		1.1.3	Poor sighted
		1.1.4	Blind
1.2	Using banknote machines	1.2.1	ATM
		1.2.2	Payment terminal
		1.2.3	Smartphone
2. RETAILERS			
2.1	Without banknote equipment	2.1.1	Small shops
		2.1.2	Shops with check-out counters
2.2	With banknote equipment	2.2.1	Staff using human-operated devices
		2.2.2	Staff using automatic devices
3. COUNTERFEITERS			
3.1	Counterfeiters targeting the public		Targeting subgroups of the public
3.2	Counterfeiters targeting shops	3.2.1	Targeting retailers without equipment
		3.2.2	Targeting retailers with equipment
3.3	Counterfeiters targeting banknote machines	3.3.1	Targeting cash-in machines
		3.3.2	Targeting payment terminals

Figure 2.12
Classification of user groups of banknotes and their subgroups.

Generic Matrix of User Function Modes of a Banknote

User functions → \ User groups →	1	2	…	j	…	f
1	1,1	1,1	...	1,j	...	1,f
2	2,1	2,2	…	2,j	…	2,f
…	...	…	…	…	…	…
i	i,1	i,2	…	i,j	…	i,f
…	…	…	…	…	…	…
g	g,1	g,2	…	g,j	…	g,f

Figure 2.13
Generic Matrix of User Function Modes of a Banknote, displaying *f* user groups and *g* user functions.

USER FUNCTION MODES							
Banknote user function		**Banknote user group**					
		1. Public, all citizens ≥ 6 years	2. Public using banknote machines	3. Retailers	4. Retailers using banknote machines	5. Counterfeiters	6. Counterfeiters using banknote machines
UIF	**User Interface Function**						
1	Recognising value	x	x	x	x		
2	Handling	x	x	x	x		
3	Checking authenticity	x	x	x	x	x	x
4	Receiving the com. message	x					
UXF	**User Experience Function**						
1	Experiencing identity	x					
2	Judging aesthetics	x					
3	Keeping confidence	x		x			
4	Reacting on main image	x					
5	Requiring sustainability	x					
6	Linking to information technology	x					

Figure 2.14
Overview of User Function Modes. Marked are the user functions relevant to a specific user group.

2.8 Qualitative ranking of UIFs and UXFs

Subsection 2.5.2 provided a tentative ranking of the UIFs and UXFs, based on argumentation. The following will provide further evidence for the proposed rankings.

Since 2003, the European Commission periodically reports in the "Eurobarometer" studies on the opinion of Europeans about "distinguishing and handling" euro coins and banknotes. Unfortunately, these studies do not discriminate between distinguishing (UIF 1) and handling (UIF 2). Over the years, people find the euro banknotes easier to distinguish and handle than the euro coins. For example, in 2015 euro banknotes score 94 % "easy", while when it comes to coins this score is 79 % (European Commission, 2015).
With the help of another study, the order of distinguishing and handling, seems to be right; the most decisive is User Interface Function of value recognition (UIF 1). When Canadian people were asked: "What is the first thing you notice on a note during a cash transaction?" over 70 % answered the determination of the note's denomination (Klein, 2004). Further evidence is delivered by a dedicated study, investigating the ranking of the UIFs, reported in figure 2.15 (Visser and Dijkers, 2013). The weighted score for each User Interface Function is also included and confirms that recognising value (UIF 1) and handling (UIF 2) are the two most relevant; note that unweighted importance of handling scored slightly lower than checking authenticity.

In general, *usability* is defined as the extent to which a product can be used by specified users to achieve specified goals (ISO, 2010a). Effectiveness, efficiency and user satisfaction are the main criteria of this standard. In case of banknotes, the UI-functions define the usability of the banknote, which may be reported by a *usability score*. Unweighted this score turned out to be for euro banknotes 6.4, on a scale from 1 to 10. The weighted usability score is higher, 6.9.
Like a usability score for the UIFs, an *experience-ability score* would indicate how people experience the new design. Figure 2.16 is prepared to demonstrate that such an experience-ability score can be calculated in a similar way as the usability score. The figures provided in figure 2.16 are presented in Italics and in a light tint, to underline that these figures represent the author's personal judgement. Future studies are recommended to provide a quantitative ranking (section 9.4).

2.9 From user functions to design requirements

The hardest part of any design process is to get the design requirements right (Norman, 2013). Design requirements are set in the first phase of a design project, at the *fuzzy front end of design* (Rhea, 2003). Indeed, for many central banks the start of a new banknote design process is an unstructured period (Firth and Church, 2009).
It is the task of the central bank to convert the user functions into design requirements (section 1.1). Once the transition is made from user functions to design requirements, the methodology can be linked to the well-documented domain of design methodology and product development (Roozenburg and Eekels, 1995; Foqué, 2010; Van Boeijen et al., 2013).

RELATIVE IMPORTANCE OF USER INTERFACE FUNCTIONS OF EURO BANKNOTES					
		Unweighted		**Weighted**	
User Interface Function		**Importance**	**Rating**	**Weighting factor**	**Weighted rating**
UIF 1	Recognising value	2.6	7.7	4.3	33.1
UIF 2	Handling	1.6	7.1	2.6	18.5
UIF 3	Checking authenticity	1.7	5.7	2.8	16.0
UIF 4	Receiving a communication message	0.2	5.2	0.3	1.6
	Total			10	
	Usability score		6.4		6.9

Figure 2.15
Relative importance of User Interface Functions of a banknote to the Dutch (Visser and Dijkers, 2013). Respondents were asked which of these four functions of euro banknotes are most important to them (4 = high importance, 1 = low importance) and how they would rate these functions on a score from 1 to 10.

RELATIVE IMPORTANCE OF USER EXPERIENCE FUNCTIONS OF EURO BANKNOTES					
		Unweighted		**Weighted**	
User Experience Function		**Importance**	**Rating**	**Weighting factor**	**Weighted rating**
UXF 1	Recognising identity	*6*	*7*	*2.9*	*20.3*
UXF 2	Judging aesthetics	*5*	*6*	*2.4*	*14.4*
UXF 3	Retaining confidence	*4*	*8*	*1.9*	*15.2*
UXF 4	Connecting with main image	*3*	*3*	*1.4*	*4.2*
UXF 5	Expecting sustainability	*2*	*5*	*0.9*	*4.5*
UXF 6	Linking to information technology	*1*	*3*	*0.5*	*1.5*
	Total			*10*	
	Experience-ability score		*5.3*		*6.0*

Figure 2.16
Relative importance of User Experience Functions based on author's judgment.

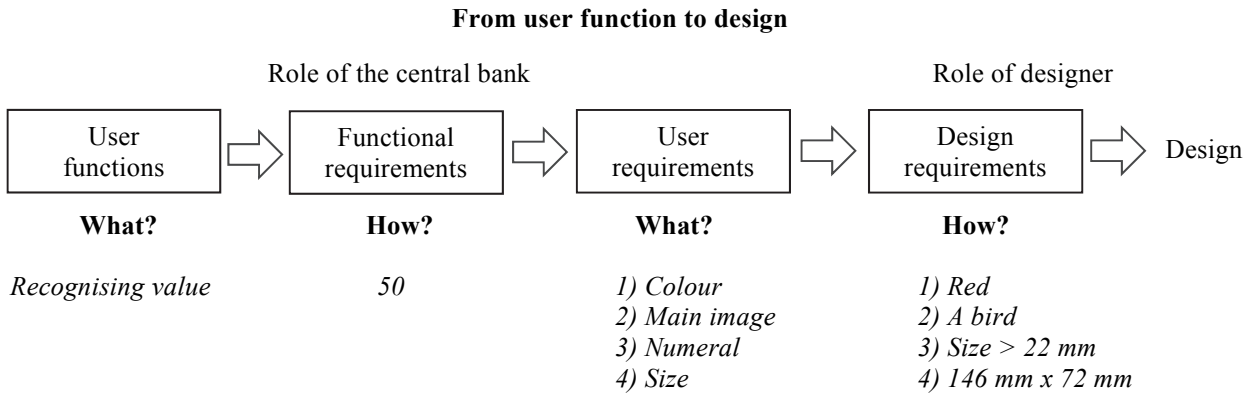


Figure 2.17
Schematic representation of the derivation of user functions to design requirements, including an example of the user function 'recognising value'. First user functions should be identified, followed by functional requirements. The functional requirements must be transferred into user requirements, based on preferences of the different user groups. Subsequently the user requirements must be translated in design requirements.

The domain of design methodology offers *function analysis,* a method based on abiding questions about 'what' and 'how' (e.g. Van Boeijen et al., 2013). Doing so, user functions can be transformed into design requirements in three stages, illustrated in figure 2.17. The first step is the transition from user functions into *functional requirements*, which are, in turn, transformed into *user requirements* and subsequently into *design requirements*. Figure 2.17 provides an example for the user function of 'recognising value', UIF 1 (what 1). The next step is the formulation of the functional requirement, for example '50' (how 1). To arrive at the design of a readable numeral 50 (what 2) is specified by user requirements (how 2), listing the typographic parameters of a user-friendly numeral, like the height of the numeral and the contrast to its background (De Heij, 2009). Similarly, other user functions can be converted to design requirements. The functional requirement for checking authenticity (what 1) is 'feel' (how 1) and users require a perceptible tactility on both the back and on the front (what 2), which can be solved by inserting a synthetic mesh band into the paper, 20 mm wide on the right side of the front (how 2).

A *user researcher* may serve as linking pin between the user and the designer (Sleeswijk Visser, 2009). The task of the user researcher is to bring in "rich experience information" to a user centered design process. A multi-disciplinary design team includes such user/usage specialists, also advocated by Van Kuijk (2010).
Adequate user requirements are based on knowledge, knowledge to be obtained from literature or to be distracted from dedicated studies, as will be introduced in section 2.10.
Linking user requirements on checking authenticity to a specific technology is beyond the scope of this thesis. The *System Approach* (De Heij, 2010a) may provide insights, as ultimately each authenticity feature has its roots in a specific physical or chemical phenomenon, like colour or resolution.

2.10 Public engagement in banknote design

The previous sections presented in several steps how the Model for Use-centered Design of Payment Instruments may assist the implementation of a use-centered design policy for banknotes. Essential for a use-centered approach is public input, the domain of *user research* or *consumer insights*. In the case of banknotes, there are three situations to engage the public in banknote design, respectively before the design process (1), during the process (2) and after the new designs are issued (3). An example for each of these situations is provided in figure 2.18.
An early example of feedforward is the introduction of a new denomination of NLG 5 in the Netherlands in 1965 (De Heij, 201a). *Before* the design process started, the Dutch were asked for their opinion on such a denomination, a banknote design topic related to UIF 1.
User feedback *during* the design process was delivered in 1985 by the Dutch blind, when they were invited to make a choice out of five specific tactile marks, which were developed for the NLG 250/Lighthouse (De Heij, 2009). In a similar exercise, the tactile structures for the euro 200 and 500 were offered to representatives of the blind community in 1997, before the selected ones were incorporated into the designs (De Heij, 2009).
An example of public input *after* the new banknote design has been issued are the bi-annual opinion polls in the Netherlands (De Heij, 2002a).

A design contest and theme selection are two more examples of public input before the design process starts. A highlight of public involvement in a design contest is the euro design contest of 1996, offering the Europeans a choice out of ten different design proposals (European Central Bank, 2003; De Heij, 2007). Selecting the design of Kalina, the EMI side stepped the preference of the European public, which was a banknote design full of people (figure 4.8a). This design by Maryke Degryse (born 1958) received the highest public score, 52 %, significant more than Kalina's design, favoured by 30 % the Europeans (De Heij, 2007). As Kalina's design was favoured by the jury over the design of Degryse, Kalina became the winner of the design contest of euro banknotes.
In 1997, for the first time, the Bank of Canada held public consultations on themes for new banknotes (Moxley et al., 2007). The resulting choice were images of Canadian wildlife. However, with the series being launched at the beginning of a new millennium, the government proposed themes that would project a more modern image of Canada. In subsequent consultations the selected design themes were "Children at play" (CAD 5), "Remembrance and Peacekeeping" (CAD 10), "Arts and Culture" (CAD 20), "Nation Building" (CAD 50) and "Exploration and Innovation" (CAD 100). Figure 3.7b displays the reverse of the CAD 10.
Central banks may not feel comfortable with the situation of involving the end user in the realisation of the design, because of confidentiality topics. Furthermore, involving the public and retailers during the design process may lead to public debates. Finally, knowledge on authenticity features may fall into the hands of counterfeiters.

Methods providing consumer insights encompass both quantitative and qualitative techniques. A clarifying scheme by Moggridge (2007) is presented in figure 2.19, describing two quantitative and two qualitative types of research on consumer behaviour. The first parameter is the sample size, which is either large enough for statistical calculations, or is not sufficient for any reliable interpretations. The second parameter is user needs, divided in 'saying' and 'doing'. An additional technique is added to figure 2.19, *in-depth interviews*, related to focus groups (De Heij, 2008a). Deeper inner considerations are unveiled best by in-depth interviewing techniques, while focus groups are more suitable to clarify qualitative variables. Asking respondents face-to-face for their consumer preferences, people may provide socially desired answers. People don't feel fully free to answer a moderator; the 'white coat effect' may play a role (Brase and Richmond, 2004).

Overviews of user involvement in the design of banknotes is provided by De Heij (2010a; 2008a; 2002a). All four types of user research have been applied to banknotes, surveys (1), focus groups (2), video ethnography (3) and observational techniques (4).

1. Surveys

Surveys provide *quantative data*. Surveys can be repeated, which provides longitudinal data, indicating trends. Usually, surveys relate to one of the users' banknote functions, like the introduced survey on the themes for Canadian banknotes (UIF 4, UXF 1).
An overview of surveys on banknotes is available (Benítez et al., 2014). Not part of this overview are the Dutch biannual public polls on 'knowledge and appraisal' on gulden banknotes, surveys relating to respectively the user functions UIF 3 and UXF 2. The results of these surveys, which started in 1981, will be presented in detail in chapter 6.
In the period 2006-2013 the Bank of England allowed citizens to suggest names for portraits to be used on future banknotes (UXF 4), which were published on a regularly updated list on the bank's website (Bank of England, 2013).
In 2013, the Russian public was asked to select one of the currency symbols for the Russian rouble, an example of exploring the identity function, UXF 1.
Also in 2013, the Bank of England consulted the public on the introduction of polymer banknotes (McLintock and Whymark, 2016), surveys referring to handling (UIF 2) and sustainability (UXF 5).
In 2014, the first surveys on an identity description (UXF 1) based on public input were organised (Pollara, 2014). Mexicans were approached for their view on the Mexican identity in 2014, resulting in a theme for a new series: "México: Historical identity and natural heritage" (Alegre Rabiela, 2016).
The latest surveys concern the introduction of female portraits on banknotes (UXF 1 and UXF 4), surveys held in the United Kingdom, Canada and the USA (subsection 5.4.4).

2. Focus groups and in-depth interviews

Focus groups provide *qualitative information* on what people say about a banknote and its features. Focus groups are usually deployed to generate ideas on a broad level. Focus groups are common in the Anglo-Saxon world and examples of focus groups providing feedback on banknotes are reported by the US and Canada (DiNunzio and Church, 2002). Focus groups are idea-generating vehicles and are also suitable to provide a general overview of opinions, beliefs and associations. However, the interaction between the members of a focus group stimulates respondents to keep giving new answers. A strong opinion leader might influence the group discussion is another disadvantage.

PUBLIC ENGAGEMENT IN BANKNOTE DESIGN		
Situation	**Type of involvement**	**Example**
1. Before start of new design	Feedforward	Denomination of NLG 5, 1965 Canadian Journey, 1997
2. During design process	Use-centered design	Selection of blind mark in NL, 1985 Euro design contest, 1996
3. After issuance	Feedback	Bi-annual opinion polls in NL, 1981

Figure 2.18
Three situations of public engagement in banknote design.

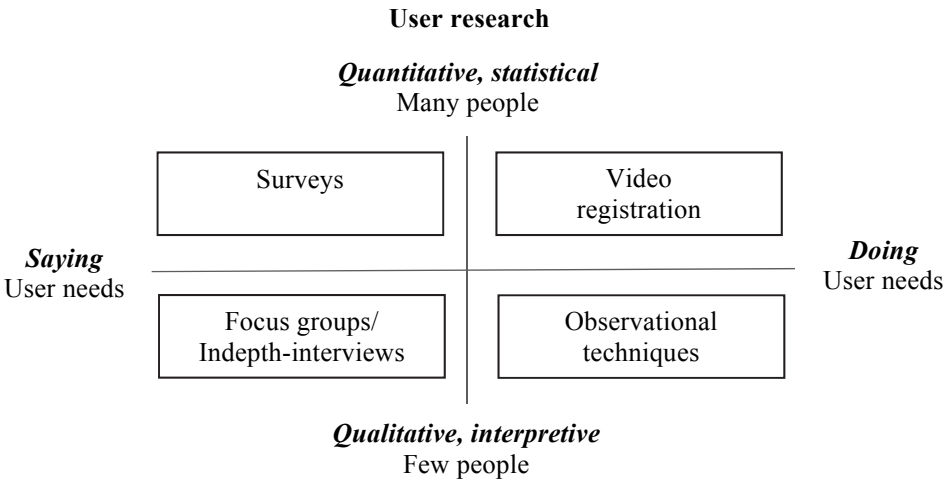


Figure 2.19
Classification by Moggridge (2007) of user research, based on user needs from saying to user needs from doing. Wording slightly adapted by author: "Video ethnography" replaced by "Video registration"; ethnography is a term used in anthropology, where the researcher observes society from the point of view of the subject of the study. In-depth interviews are added to the quadrant "Focus groups".

FOCUS GROUPS AND IN-DEPTH INTERVIEWS COMPARED	
Focus groups	**In-depth interviews**
- More common in Anglo-Saxon world	- More common on the continent of Europe
- For strong opinions, high public involvement	- For low public involvement
- Interaction between participants	- No interaction between participants
- No individual test possible	- Individual test possible
- Opinion leader might influence others	- Real opinion of one person
- Idea generating	- Not conducive to many ideas
- Less suitable for reaction to range of products	- Reaction to range of products

Figure 2.20
Some differences between focus groups and in-depth interviews.

In 2004, a first publication appeared on public preferences for authenticity features (UIF 3), a combined study by the central banks of Canada and the USA (Setlakwe and DiNunzio, 2004). Because of these studies, the Bank of Canada introduced in 2011 a very wide foil stripe in their polymer notes, as far as known, the first example of an authenticity feature grounded on public input.

An alternative for focus groups are indepth-interviews, an individual approach, providing insights into deeper conscious and subconscious attitudes and beliefs. Therefore, indepth-interviews are the most appropriate method to gather the opinion of respondents about a new banknote design. Indepth-interviews are also providing insights in the decisions respondents take, when they are asked to do a test with banknotes, like checking a banknote's authenticity. People are very well able to react to a range of products, but, on the on whole, are not very apt at responding to (orally presented) concepts (Van der Horst et al., 2017). Up to 15 different banknotes may be offered to a respondent.
Figure 2.20 contrasts the relevant differences between focus groups and in-depth-interviews.

3. Video registration

When it comes to user behaviour with banknotes, video registration is not widely applied, probably because the analyses of video recordings of many respondents is a large effort.
Video registrations are often made during in-depth-interviewing, as was the case in a qualitative study to euro banknotes (Van der Horst et al., 2017). One more example is the study on how people take banknotes (Lingnau et al., 2007), reported in subsection 6.3.1.

4. Observational techniques

Like video registration, observational techniques are not widely applied in user research concerning banknotes. An example is eye mark tracking, which will be introduced in more detail in subsection 5.3.1.

2.10.1 Public input on new banknote design by feedforward

A central bank may explore the public's opinion on their need for a new denomination or on their need for replacing existing banknotes by new designs (subsection 1.3.2). Both are examples of public input by feedforward.

A special category of feedforward involvement is privately organised banknote design competitions, like the "Graphic ECU Competition". The winning design is shown in figure 2.21a and another entry featured a portrait of Europa, shown in figure 2.21b (De Heij, 2012). One more example of a private design initiative is the "The Dollar Redesign Project", a platform on the internet, established in 2009. Inspired by the motto 'change' of President Obama (born 1961), a group of American designers thought that this would be their chance to introduce new ideas for US dollar designs. Two examples are shown in respectively figure 2.21c and d. Usually, such initiatives are ignored by central banks.

2.10.2 Public input during the design process

Participants in a traditional banknote design project are the design manager of the central bank, the banknote designer and the producer (De Heij, 2017). Usually, these three parties do not invite the public for input during the design process. The presence of producers could be reduced in a use-centered design, while other experts may come in. An example would be the entrée of a *user specialist* and/or a *usability tester,* already introduced in section 2.9, specialists contributing perception tests or other services to ensure user satisfaction of future banknotes.

Private banknote design initiatives

The Graphic ECU Competition (1993)

a)

b)

c)

d)

Dollar ReDe$ign Project (2009)

Figure 2.21
Banknote designs proposed within the Graphic ECU Competition (a, b) and the Dollar ReDe$ign Project (c, d).
a) Designer unknown, selected design within Graphic ECU Competition (1993).
b) Design by Codina & Fontanals, winning design of the Graphic ECU Competition (1993).
c) Design by University of Minnesota (2009).
d) Barbie on a one dollar design by Sandra Hill (2009).

2.10.3 User feedback after issuance

The last variant of user input on banknote design is the collection of user feedback after the new banknote has been brought into circulation. Biannual surveys by DNB started in 1981, aiming for user feedback according to the *Model for User Feedback on Banknotes*, shown in figure 2.22 (De Heij and Koeze, 1988; Van Gelder and De Heij, 1992; De Heij, 2002a).
A series of banknotes consists of several components, too many to be all included in a questionnaire. A questionnaire should have an acceptable length to the respondents. Therefore, the commissioned agency (NIPO, Amsterdam) advised the maximum time needed for answering the survey questins not to exceed 15 to 20 minutes. Indeed, a good advice, as over the decades this time span turns out to be right to keep the attention of the respondent. To keep the interview within such a time span, Dutch respondents are interviewed on two denominations. The first is a reference, an *anchor not*e, and the second is a banknote of special interest, usually the latest model issued. The anchor note should be well-known and should be frequently used. Preferable the anchor note is taken from the centre of the series. First, the NLG 100/Snipe (1981-1993) functioned as anchor note, followed up by the NLG 100/Little Owl (1993-2001) and the EUR 50 (2002-2017).
The surveys are based on recall, respondents are not interviewed on underlying motives. Asking respondents about the why-they-*use*-this-or-that is believed to be pointless, just as asking to the why-they-*like*-this-or-that (Hesse-Biber and Leavy, 2010).
When the public is asked for input, they should be informed about the results. Since the beginning DNB has published the outcome of the public's valuation of banknotes (Den Butter and De Heij, 1985; De Heij and Koeze, 1988; for the other publications, see the author's references).
Furthermore, the findings have been used to instruct Dutch banknote designers and in consultations with other central banks.

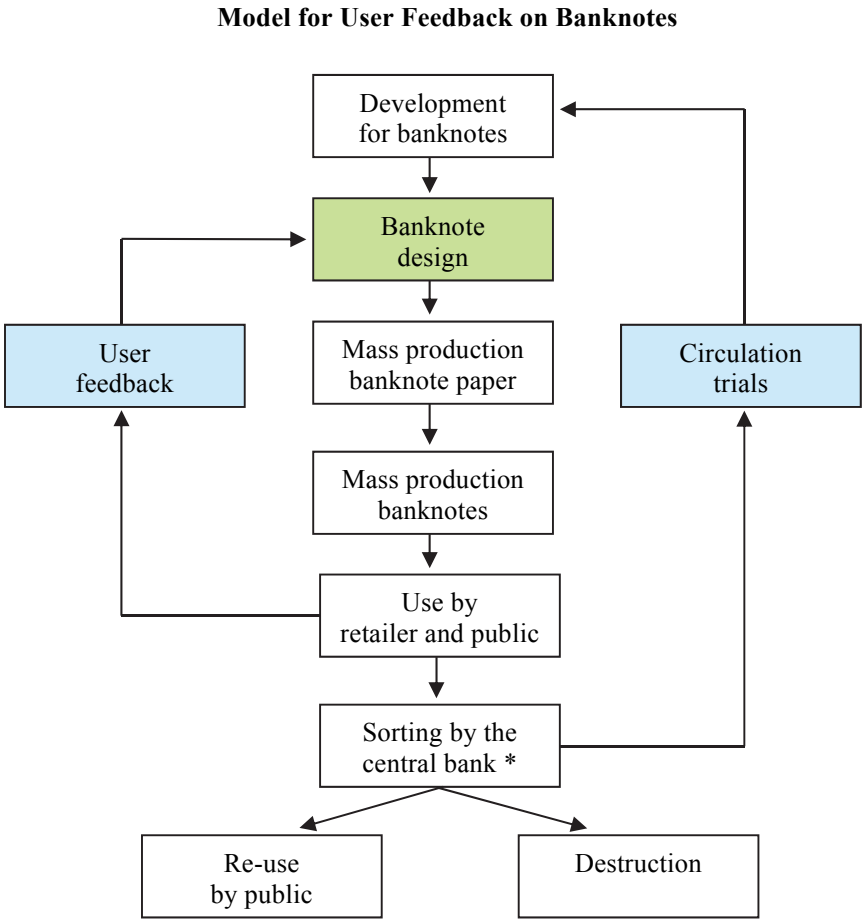


Figure 2.22
Model for User Feedback on Banknotes. Banknote design and feedback on the design are core activities of a central bank, underlined by respectively the green colour for banknote design and the blue colour for the two feedback loops, being user feedback and circulation trials.

2.11 Conclusions on model building on use-centered design of payment instruments

Academic model building on banknote design is at its infancy. Model building turned out to be successful by linking two existing knowledge domains, respectively the economic functions of money and design methodology. The adopted design methodology builds further on Use-centered Design and Interaction Design. Interaction Design discriminates between the use and the experience of a banknote. Using these two parameters, new banknotes designs can be classified in four basic models and for each model a recent example is identified.

The economic functions as defined by Jevons are transferred into user functions of banknotes, which became the fundament of the Model for Use-centered Design of Payment Instruments. The Upid-Model lists four User Interface Functions (UIFs) and six User Experience Functions (UXFs). These user functions can be ranked on the basis of public preferences. The developed Model is not only applicable to banknotes, but also to other payment instruments. Since the Model is more broadly applicable, it is not named a Model of Use-centered Design of Banknotes, but a Model for Use-centered Design of Payment Instruments, which is applied to banknotes.
Combining the user satisfaction on all UIFs leads to a usability score. Similarly, an experience score indicates the user satisfaction on all UXFs.

Applying Jevons functions on existing banknote series shows that there is no clear separation between denominations serving as a ‘means of payments’ and denominations serving as ‘a store of value’.

Users may perceive a banknote in different modes, which depends of the users’ interest. User Function Modes combine the user function and the user group, for example, the public (user group) will be in value recognition mode (UIF 1) when they accept the change. User functions are defined within the Upid-Model for the three main user groups: the public, retailers and counterfeiters.

Essential to a use-centered design policy for banknotes is to gain public input in all three stages: before, during and after the design process.
In the Netherlands, user feedback is obtained with the help of the Model for User Feedback on Banknotes, providing insights on the usability and the ‘experience-ability’ of the last released banknote.

Form follows function.
Louis Henry Sullivan (1856 - 1924)

CHAPTER 3
USER INTERFACE FUNCTIONS

3.1 Introduction

The question answered in this chapter is: What is known about the User Interface Functions of a banknote?

Designers will know "Form follows function", the famous adage of Louis Sullivan at the heading of this chapter. Its origin goes back to 1896, when it was formulated as "Form ever follows function". This principle leads this chapter on the design of User Interface Functions.
When a central bank has little knowledge on user functions, it will not be able to formulate user requirements. Subsequently, design requirements will remain unidentified, which may result in suboptimal banknote designs. This seems to be especially true for the UIFs as central banks and their designers tend to focus on the UXFs, like the main image. However, once a new banknote design is issued people will lose their interest in the UXFs, while they must undergo the suboptimally designed UIFs at each cash payment.
Publications have been made on user behaviour with banknotes, like a study on cash handling habits of Canadians (Balodis, 2012) and a study on how Mexicans perceive their banknotes (Banco de México, 2014).
Literature on User Interface Functions of banknotes is limited, often focussing on one user function. The following literature is listed according to the Model of Use-centered Design of Banknotes:

UIF 1 - Value recognition is the most important UIF and is especially of interest to the visually impaired. They are divided into three subgroups: colour blind, poor sighted and blind. How banknotes are denominated by the colour blind (Walraven, 2003) and the poor sighted (National Research Council, 1995) is described. The smallest subgroup, the blind, receives most attention (Wertheim, 1990; Koeze, 1990; Lederman and Hamilton, 2002; Dinse, 2008). A more general study on the visual accessibility of banknotes is reported by Williams and Anderson (2007). Other central banks also report on their efforts to meet the requirements of the visually impaired, like the Bank of Canada (Samuals, 2009) and the Reserve Bank of Australia (Springer et al., 2015).
UIF 2 - One of the relevant design parameters to the blind is the banknote's format (National Research Council, 1995).
UIF 3 - A historical review of the development of authenticity features is available (Schell, 2007). Furthermore, the National Research Council made several publications on authenticity features (National Research Council, 1985; 1987; 1993; 2007). A publication by the Bank of Canada is available on tentative user requirements of authenticity features (Church and Setlakwe, 2004).
UIF 4 - People will remember an image better when its name is printed near the image (Peek, 1972). A communication message will be remembered well when it follows the "Six Principles of Sticky Ideas" (Heath and Heath, 2007). The mass communication function of money is analysed by Lauer (2008). Communication themes on banknotes were object of study by applying "The Function Systems of Society" (Roth, 2014).

This chapter reports on the four User Interface Functions: recognising value (section 3.2), handling (section 3.3), checking authenticity (section 3.4) and receiving the communication message (section 3.5). Characteristic design elements are analysed from a usage perspective. This chapter ends with conclusions on UIFs of banknotes (section 3.6).

3.2 Recognising value (UIF 1)

Recognising value is the most important User Interface Function of banknotes (section 2.8). People like to denominate a banknote fast, within an instant. This imposes requirements on the design, as value recognition is done under different lightning conditions (subsection 5.2.1).
All citizens should be able to denominate banknotes and one size must fit all (section 1.1). When the user requirements of the visually impaired are determined first, normal sighted people will also be able to recognise the banknote's value, so is the assumption. Visually impaired consist of three subgroups: colour blind (1), poor sighted (2) and blind (3). In general, these three subgroups have similar basic needs. First, they want to have 'meaningful access to banknotes' and second, they want to be able to use banknotes like normally sighted people do. The number of denominations is one more relevant design parameter, as with more denominations, the denominating process will be less efficient.

3.2.1 Denominations

The more denominations there are, the more difficult it is to determine the value of a single piece. Therefore, the blind require to: "minimise the number of coin and banknote denominations" (European Blind Union, 1995). Furthermore, when a serial design creates too many and too uniform banknote designs, people may take non-existing banknotes for real, as has been the case for denominations of 30 and 300 euro (De Heij, 2007).
If there would be just one banknote, it would not be difficult to tell its value. However, in such a case it would not be possible to settle all amounts that payee and payer may agree upon. This raises the question of what is an optimal set of denominations. A study of denomination schemes applied in 35 countries showed a typical distribution of 6 coins and 6 banknotes (Payne and Morgan, 1981).

Old silver and gold coins were literally divided into two equal pieces, following the mathematical sequence of 1 - 1/2 - 1/4 - 1/8 - 1/16 - 1/32 - 1/64. This principle of 'divide by two' is often followed for *coin denomination schemes*. Opposite, *banknote denomination schemes* are often following multiplication factors, which were often irregular, like in the case of Dutch banknotes around 1860 (25, 40, 60, 100, 200, 300, and 1,000).
Denominations of early banknotes were not fixed; any round value asked for could be filled in. Also the date was filled in by hand and the notes were signed by hand. For this work, the Bank of England employed in 1694 three cashiers (Byatt, 1994). In 1725, prefixed denominations were introduced in England. Banknote denomination schemes could include as many as 12 denominations, like the Russian rouble series introduced in 1919. In 2002, the euro received 7 denominations, which was an answer to a variety of number of denominations used in the countries that started to pay with the euro, ranging from 3 denominations in Luxemburg to 8 denominations in Germany. Indeed, nowadays there is a worldwide variety on denomination schemes used, like 4 denominations in Great Britain and Japan, 5 denominations in Denmark, Norway and Thailand and 6 denominations in Kuwait.

Finding an optimal denomination structure is an exercise in mathematics, a problem of optimisation on multi-criteria. The basic question is how to pay an amount by using a minimum on coin and banknote denominations (Hentsch, 1973, Cramer, 1983; 1986). Modern denomination schemes are based on the decimal system, but alternative systems are also thinkable, like schemes based on powers-of-two (1, 2, 4, 8, 16, 32, etc.) or powers-of-three systems (1, 3, 9, 27, 81, etc.) (Van Hove, 2001; Pattanarangsun, 2011). Non-decimal systems may have theoretical efficiency advantages over decimal systems, but do not match with the public's preference for a decimal system. In case of electronic payments people also prefer the decimal system, using two places after the decimal point. From this point of view, it is remarkable that the digital currency Bitcoin uses eight decimal places; the smallest amount that can be handled in a transaction is 0.000 000 01 (1 satoshi). Bitcoins can be traded in any amount, but people prefer fractions related to a decimal system like 1 bitcoin, 0.01 bitcoin (1 bitcent) and 0.001 (1 bitmill).

Triggered by the transition of the Netherlands gulden to the euro, an efficiency study has been made to denomination sequences (Kippers et. al, 2002). This study concluded that the euro denomination system (0.2 - 0.5 - 1 - 2 - 5) is more efficient than the Dutch guilder system (0.25 - 1 - 2.5 - 5), because of the introduction of a 50 eurocent piece, which denomination, 50 cent, was not part of the gulden sequence.
Rounding-off prices to 0 eurocent or 5 eurocent is more efficient without the 1 and 2 eurocent, so is the conclusion of another study (Kippers and Franses, 2003). Cost savings by retailers and society (subsection 8.2.3) were one more argument for the abolishment of these two coins in 2004. Leaving out a denomination of 50 euro has a greater negative effect on payment efficiencies with the euro, then skipping the 10 and 100 euro denominations, so is another finding of Kippers and Franses.

The unit of a currency is the 'one' or '1'. Usually a cash payment system splits the denominations in two payment channels (subsection 2.4.2). The coin payment channel consists of *c* coin denominations and the banknote payment channel of *b* banknote denominations, as schematically drawn in figure 3.1 (De Heij, 2010a). The division is usually made at the centre of all denominations. Whether the unit one is a coin or a banknote is influenced by culture. In case of the US dollar the unit one is represented by a banknote and in case of the euro it is a coin, while the value of one dollar and one euro are about similar. Banknotes using lower denomination values then the currency unit one are rare. The Kuwaiti Dinar (KWD), issued since 1961, is an example, incorporating banknote denominations of ½ and ¼ KWD.
In this context, it is noteworthy that the visual representation of crypto currencies is often displaying a coin and not a banknote (figure 2.7i). *Tokens* are also often referred to as coins (figure 4.12b).

Central banks may have both a coin and a banknote of the same denomination. Usually, a coin is introduced with the similar value as the lowest banknote denomination and after some time the banknote is withdrawn. This was the case in Great Britain, where in 1983 a one pound coin was introduced, which co-circulated with a banknote of the same value. After some years, the one pound notes were withdrawn. The US Treasury aimed for a similar approach, respectively in 1971, 1979, 2000 and 2007. A one dollar coin was introduced, which should co-circulate with the well-known one dollar banknote. In this case, people felt uncomfortable and their user behaviour was not to accept a one dollar coin. If they did, they tried to spend this coin first, a habit which can be explained by Gresham's Law as will be elaborated on further on. Furthermore, coins and banknotes are perceived differently; US citizens perceive the value of a one dollar banknote almost twice the value of a one dollar coin (Alter and Oppenheimer, 2008).
The opposite situation may also happen, the introduction of a banknote, which co-circulates with a coin of the same value. In Germany, a coin and banknote of 5 D-Mark co-circulated for more than 40 years. When in 1992, a new banknote design for this denomination was introduced, people preferred to use the existing coin over the new, unknown banknote, an exceptional case.

Filling in a denomination scheme requires a mathematical principle. Taking the unit 1 as a nucleus, there are four basic approaches (De Heij, 2012). The scheme used most frequent is 0.2 - 0.5 - 1 - 2 - 5, creating an equal type of denominations for both coins and the banknotes (e.g. euro, Japanese yen). A second scheme divides the unit 1 into halves for coins and redoubles this unit for banknotes, 0.25 - 0.5 - 1 - 2 - 5 (e.g. Sri Lanka, USA). A third scheme divides coin denominations into halves and multiplies banknote denominations by 2.5, typically being 0.25 - 0.5 - 1 - 2.5 - 5 (e.g. Lebanon, South Sudan, former Netherlands gulden). Finally, there are irregular denomination schemes, for example 0.15 - 0.5 - 1 - 3 - 5, schemes used by former East European countries and Russia, but today abandoned, although a 3-peso banknote is still used in Cuba.

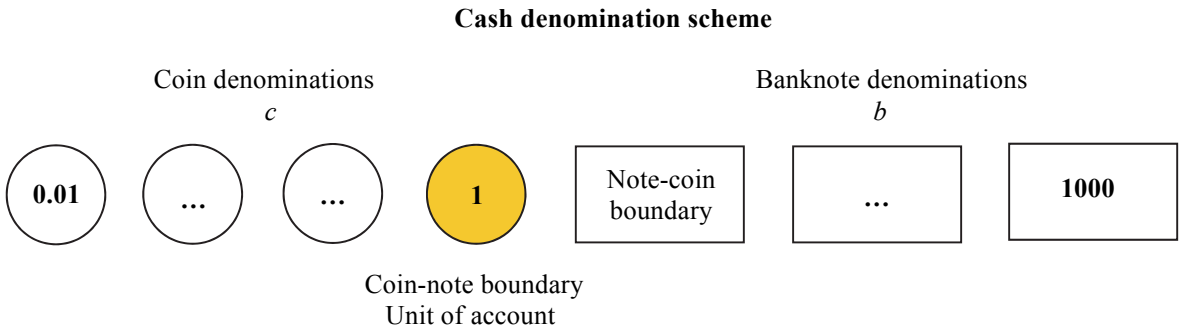


Figure 3.1
A conceptual model of a cash denomination scheme, using c coin denominations and b banknote denominations. The total amount of denominations is $c + b$. In a symmetric cash denomination structure, the unit of account is the centre of all denominations according to $c = b$. Other options are $c = b + 1$ or $c = b - 1$.

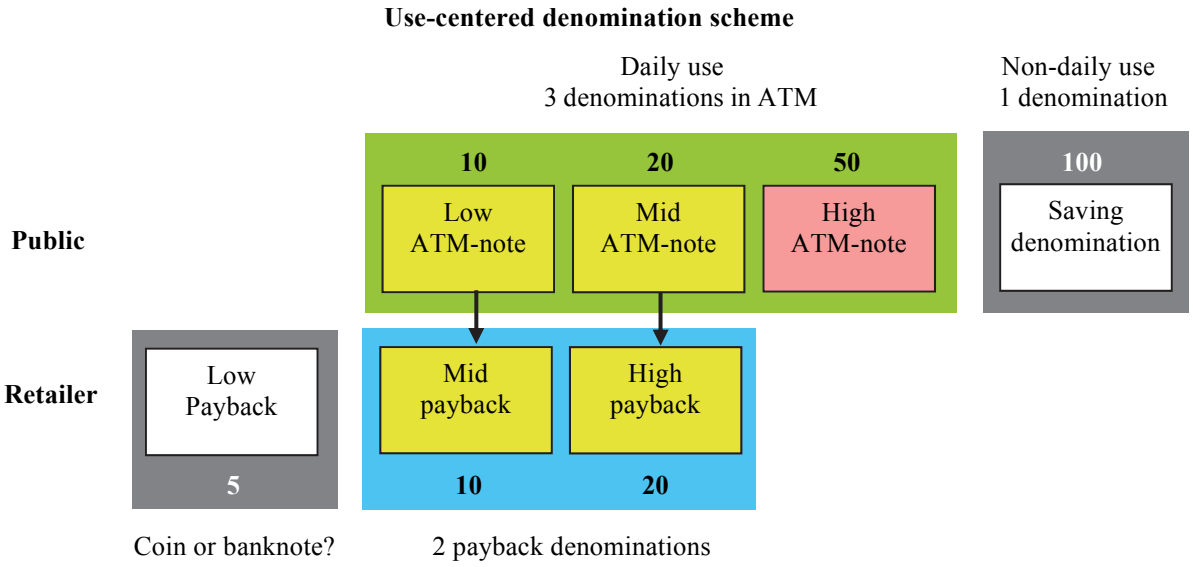


Figure 3.2
A use-centered construction of a denomination scheme. The public withdraws three denominations from an ATM. Retailers need a low payback denomination, which could be a coin or a banknote.

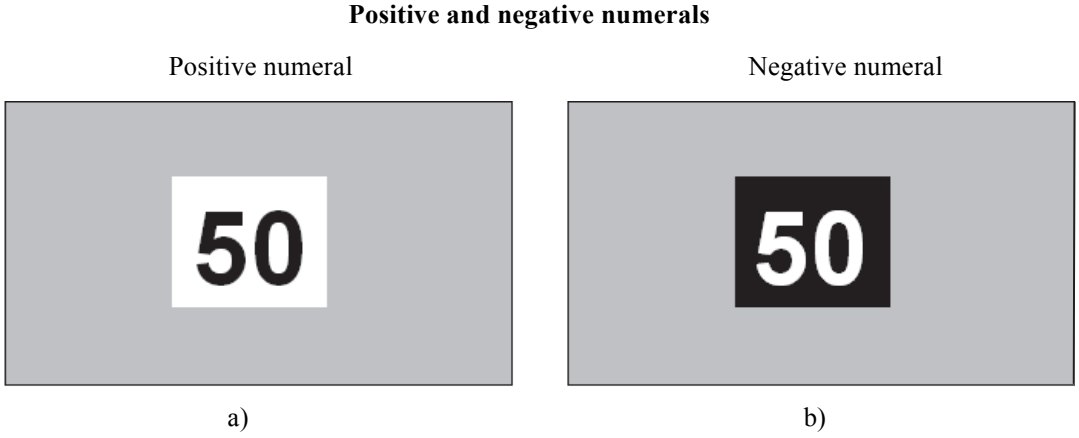


Figure 3.3
About half the people favour the design on the right and the other half the design on the left.
a) Positive numeral.
b) Negative numeral.

An alternative denomination scheme is the use-centered denomination scheme as provided in figure 3.2, based on the denominations people withdraw from an ATM. In general, ATMs offer three different *ATM-notes*, low, middle and high. The high ATM-note is usually the most frequently withdrawn denomination, like the 50 euro in the Netherlands, where the mid and low ATM-notes are respectively the 20 and 10 euro. The preference for specific denominations within countries of the Euro Area is influenced by culture. While the most popular ATM-note in Germany and the Netherlands is the euro 50, in France this is the euro 20. ATMs in Austria also provide the euro 100.

When the euro was introduced in 2002, several ATMs provided the new 5-euro denomination. However, the withdrawals of 5-euro banknotes dropped in the Netherlands from 9 % in 2003 (Kippers and Franses, 2003) to close to zero in 2007 (De Nederlandsche Bank, 2007).
A fourth denomination, not being an ATM-note, may serve as a saving denomination or *hoarding denomination*. Such a saving denomination could be designed along other lines, while it may still be perceived as part of the series design, as will be elaborated on in subsection 7.2.3
The presented use-centered denomination scheme is based on the following reasoning. The public mainly withdraws high ATM-notes and these denominations are taken to the retailers. The retailers deposit these notes to the commercial bank, leading to a high *return frequency* of this denomination; the same euro 50 banknote is received up to six times per year by sorting centres in the Netherlands. Because of its unilateral role in the cash cycle the high ATM-note in figure 3.2 is marked with a red colour. Retailers need to have payback denominations for their clients and the mid ATM-note is their highest payback denomination. Another unilateral role is fulfilled by the low payback denomination. When this denomination is a banknote, like the euro 5 or the one US dollar, these notes stay in circulation and tend to wear out.

The previous paragraph clarified that the lowest denomination people withdraw from an ATM should be the *note-coin boundary.* Within a *cash denomination scheme*, this is the first banknote denomination after the highest coin. An alternative to the note-coin boundary is the *coin-note boundary*, being the highest coin denomination, followed by the lowest banknote denomination. However, the note-coin boundary is the most common terminology. Over the years, inflation will push the note-coin boundary upwards, the lowest coin values disappearing first.
The public's perspective on the note-coin boundary has been object of study by Payne and Morgan (1981), reporting that this boundary depends on the average day's pay (D). The note-coin boundary is found to be either at D/50 or D/20 for denomination systems using banknotes of 10, 20 and 50 units. The inflation rate is one more variable influencing the position of the note-coin boundary. A central bank should be careful with issuing coins when the economy shows high inflation rates (e.g. > 10 %), as coins may disappear from circulation, especially when the minting costs (intrinsic value) exceed the denomination value (extrinsic costs).
A third criterion to set a note-coin boundary is the fitness of the banknotes of the lowest banknote denomination. More than others, the denomination at the note-coin boundary suffers from wrinkles, tears, soil and missing pieces. Such banknotes may become very unfit, because they are not re-used in ATMs and therefore tend to stay in circulation. Koeze (1988; 2003a) defined the journey that a note makes from the moment it leaves the central bank until its returns as a cycle; a banknote always makes one cycle. When the average number of cycles tends to one, a banknote denomination should be replaced by a coin; new banknotes are issued and are destroyed when they come back to the central bank. The average number of cycles of Dutch banknotes of various denominations was in 1987 between 1.7 and 5.6.

Replacing a banknote by a coin may meet resistance from the public, especially when people perceive a banknote as more valuable than a coin. This phenomenon is an example of 'Bad money drives out good money' as first observed by Thomas Gresham (1519-1579) and coined "Gresham's law" in 1858 by Henry Dunning Macleod (1821-1902). Gresham observed that people could scrape small pieces of gold or silver from their coins and could spend these clipped coins without people noticing.

Another malicious practice dating back to the times when coins had an intrinsic value was to replace parts of a coin by less noble metals. To be certain, the weight of the coin should be checked with each transaction, a time-consuming affair. Obviously, people opt to spend an inferior coin first. This phenomenon was also clear to Isaac Newton (1643-1727), the famous English physicist. In 1696, when he became warden of the Royal Mint in London, Newton introduced the understandings of the *intrinsic value* and the *extrinsic value* of a coin. The metal value is the intrinsic value and the nominal value is the coin's face value. When the intrinsic value is higher than the extrinsic value, people will collect coins and will tend to keep them. As producer of coins, Newton brought the sizing of the coins to greater exactness, so that the intrinsic value would show less deviations.
The intrinsic value of banknotes is close to zero and therefore people will not tend to keep them, an expectation confirmed by a banknote circulation trial in the Netherlands (Koeze, 1979).

The denomination scheme 0.2 - 0.5 - 1 - 2 - 5 is the most common, as introduced. To prepare Europeans in 2001 for the advent of the euro coins and banknotes major information campaigns were organised. The result of these campaigns was that the denominations best recalled were all multiples and fractions of ten: 0.10, 10 and 100; the other was 50. Indeed, fractions of 2 are unpopular; 2 eurocent, 2 euro, 200 euro were the least known values prior to the launch of the euro. These findings confirmed earlier studies done in the Netherlands, telling that people recall first multiples and fractions of 10, followed by 5 and 2 (De Heij, 2012). The figure 2 is also unpopular within other currencies, like in the United States and Japan. A 2-dollar banknote has been in circulation since 1862, nevertheless this is one of the least popular. Although there are in Japan just 4 denominations, the 2,000 yen is seldom used. The purchasing power is also an aspect of a denomination. In Norway, for example, the 200 kroner (about 22 euro) is today more popular than the 100 (about 11 euro).
People may not be aware of all denominations, as was the case during the change-over from gulden to euro in the Netherlands in 2002. Several Dutch citizens think there is a 1,000-euro banknote, which may be explained by the existence of a former 1,000-guilder denomination. The spontaneous awareness of this non-existing denomination of 1,000 euro increased from 2 % in 2002, to 11 % in 2011 and reached in 2015 a score of 20 % (Randsdorp and Zondervan, 2015).

3.2.2 Numerals

Once the denomination scheme is set, the banknote designer should emphasise the banknote's value. The numeral is important; 70 % of the Canadians determine first the denomination of a banknote during a cash transaction, either by the numeral or by the colour (Klein et al., 2004).

Traditionally, the value of a banknote was handwritten in text, without any numerals. Coins in the United States still do not carry any numerals; there is no '10' on the dime or '25' on the quarter. The first numerals on banknotes were rather small and their size increased over the decades.
Numerals can be printed as a *positive numeral* (figure 3.3a) or as a *negative numeral* (figure 3.3b). The first numerals appearing on banknotes where negative numerals to prevent that numerals could be removed, for example by bleaching, and subsequently be replaced by a higher value. Several measures were taken to counteract this type of forgery. The negative numerals were printed within a complex pattern of security printing, like *guilloches*. The printing was done with *fugitive inks*, inks that dissolve during the bleaching process (McCabe, 2016). Furthermore, denominations were printed on different paper tints. With such measurements, the numeral design aimed for authenticity (UIF 3) instead of recognising value (UIF 1).
In 2016, banknotes in Venezuela became worthless because of high inflation. As the dimensions of these notes (156 mm x 69 mm) is almost like the US dollar (156 mm x 66.3 mm), these notes were collected and, after bleaching, fake dollars were printed on the Venezuelan paper (e.g. The Guardian, 2016a).
Readability of numerals depends on the typographic design, the quality of the eyes, the reading distance and light conditions (De Heij and Koeze, 1987; De Heij, 2009). The design of numerals on modern banknotes is often suboptimal when it comes to their readability.

The following introduces the most relevant design parameters of the typographic design of numerals on banknotes, starting with the size of the numeral (topic 1), followed by a positive or a negative representation (topic 2), contrast (topic 3), font type (topic 4) and the use of colours within the numeral (topic 5).

1. Numeral height

Numerals on old banknotes were small and, usually, their numeral height did not exceed 5 mm. The first Monopoly Money was introduced in 1935 and was optimised for quick value recognition during the game. Monopoly Money is well-known for its large numerals and vivid colours (figure 3.4). This play money inspired the Dutch banknote designer Robert Oxenaar, introduced in subsection 1.1. Oxenaar's first banknote design received a numeral with a character height of 18 mm (NLG 5/Vondel 1, issued in 1966). Banknotes of other central banks also showed large numerals, like for example the series of Swiss banknotes of which the first model was issued in 1956, but not in bright colours as introduced by Oxenaar. The next banknote by Oxenaar was even more innovative, the NLG 10/Frans Hals (figure 3.5). Because of its bright colours and large numerals, these banknote designs were associated with 'Monopoly Money'. Play money is associated with phoney, undermining confidence, an example of perceiving a banknote in UXF 3. From the 1970s, there was a trend to improve the readability of the numerals. US dollar denominations received in 1996, a 'tall numeral' of 14 mm (figure 3.6b), followed in 2008 by a second enlargement to 26 mm (figure 3.6c). To fit the numerals of the USD 100 into the note, the numerals had to be made smaller and had to be rotated by 90° (figure 3.6d).
In 2001, the Bank of Canada introduced larger numerals (22 mm) on their banknotes and brighter colours (figure 3.8). These numeral sizes come close to the advice of Ware (2008), telling that optimal perceivable design elements on reading distance should be about 30 mm x 15 mm. Indeed, when banknote numerals become too large, larger than 50 mm, people may get difficulties with focussing (National Research Council, 1995).

2. Positive and negative numerals

Figure 3.3 displays a positive and a negative numeral. Which of the two reads best? A general answer comes from Allen and Straub (1956). When viewed under *low* levels of illumination, white characters on black background are better legible than black characters on a white background. The opposite, black numerals on a white background, become more legible under *high* illumination. When asked for their preference, about just as many Canadian poor sighted preferred a positive numeral as a negative numeral, although slightly more opted for the positive variant (Spencer and Dupuis, 2007). Based on this study, the Bank of Canada concluded that both should be present on the notes, a positive variant for high levels of illumination and a negative variant for low levels of illumination. Another novelty of this Canadian series is to feature large numerals on both sides, shown in figure 3.7 (Samual, 2009). Elderly German citizens prefer a negative numeral on the euro, one of the conclusions of a small-scale study by Müller (2011).

3. Print contrast of numerals

The design of the NLG 10 (figure 3.5a) did not only show large numerals, the numerals were also printed in a high Print Contrast Ratio (PCR) as defined by Michelson (1927). The higher the PCR, the higher the reading speed; the PCR of black letters on white paper is close to 100 %, receiving higher reading speeds than any other colour combination (Tinker and Paterson, 1932; Tinker, 1963). Green-on-white was 3.0 % slower, green-on-red 10.6 %, red-on-green 39.5 % and black-on-purple 51.5 % slower.

Monopoly Money

Original 1935 Around 1938

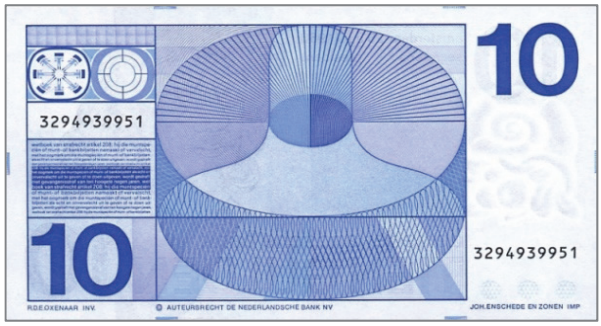
a) b)

c) d)

Around 1965 Around 1985

Figure 3.4
Monopoly money is optimised for quick value recognition during the game. Several designs are made (e.g. http//monopoly.cdpdx.com):
a) Original form 1935 (USA).
b) Around 1938 (The Netherlands).
c) Around 1965 (The Netherlands).
d) Around 1985.

Innovative banknote, Netherlands (1971)



a) b)

Figure 3.5
First banknote with bright colours and large numerals, the NLG 10/Frans Hals issued in 1971. It is also the first banknote with tactile marks for the blind. Another first is the introduction of 6 mm length difference between the denominations, keeping a single note height. It was also the first banknote with machine readable features. The sorting machines of DNB registered the non-fluorescence of the banknote paper, the gravure printing (ISARD-detector) and two cameras registered the banknote numbers (type OCR-B).
a) Front.
b) Reverse.

Numeral development on US dollar

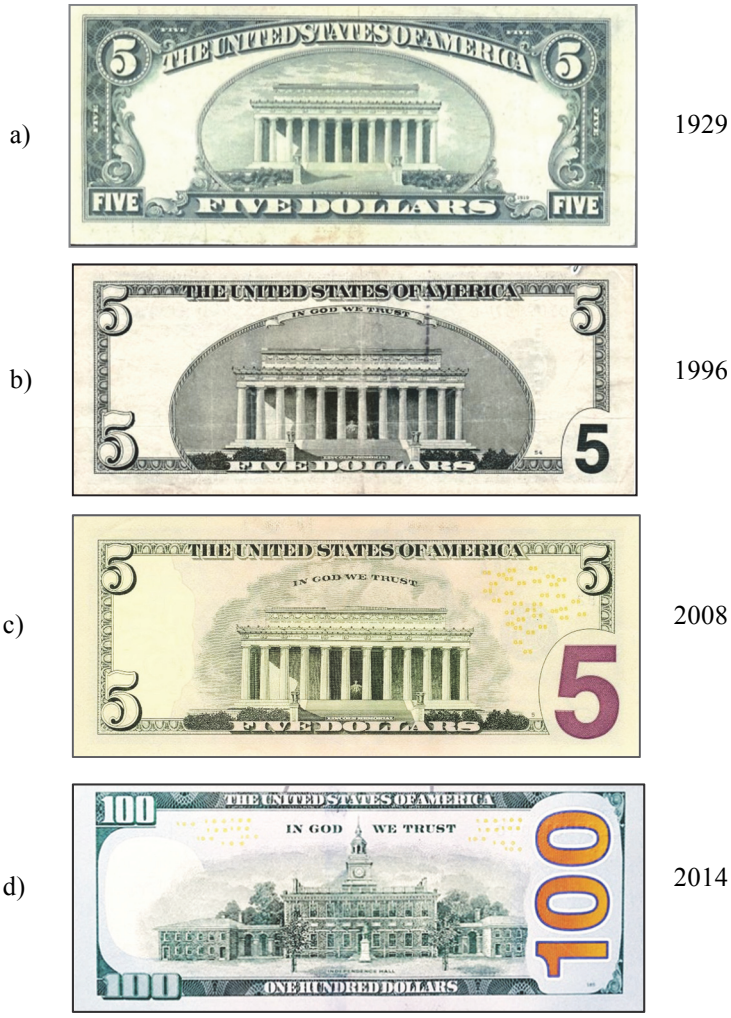


Figure 3.6
Development of the numeral sizes on US dollar banknotes.

Innovative banknote, Canada (2001)

Front Reverse

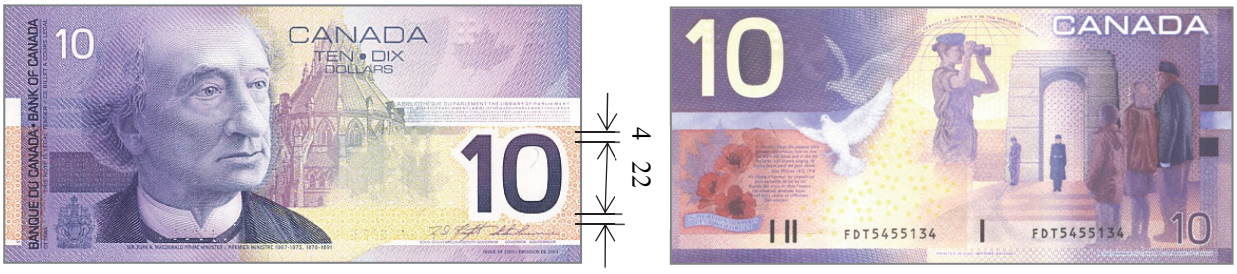


Figure 3.7
Innovative banknote for the visually impaired, the Canadian 10 dollar issued in 2001. Large numerals (22 mm) on both front and reverse. One in positive and one in negative. Furthermore, the numeral on the front received a high tactility.

The high contrast numerals on Dutch banknotes were appreciated by the public, triggering DNB in the 1980s to require a PCR > 80 % for future Dutch banknotes. The National Research Council in the United States, advising for US dollar banknotes, copied this requirement from the Dutch, at the same time increasing the value to PCR > 85 % (National Research Council, 1995). The Bank of Canada targeted for their banknotes of the Canadian Journey series a PCR > 80 % (figure 3.7). They reported that this target could not be reached and came as close as 78 % (Spencer and Dupuis, 2007). Almost forty years after being issued, the PCR of the numeral on the NLG 10/Frans Hals was measured, and its value came out on 69.2 % (De Heij, 2009). This publication also reports on the PCR's of other banknote models.

4. Font type

The *letter type* or *font type* is one more relevant variable to readability. Well-known banknotes using a *serif letter type* are the US-dollar notes, while Canadian banknotes and the euro, use a *sans serif letter type*. Serifs are the small elements added to the edges of a letter. The "euro style sans-serif" is the font type of the numerals on the CAD 10 (figure 3.7), slightly modified to address concerns raised by invited vision specialists (Spencer and Dupuis, 2007).
In general, the readability of a letter or numeral can be analysed on a grid with black and white squares, like the numeral 50 shown in figure 3.8a. When it comes to readability the 5 is the most critical numeral. The 5 is constructed of five horizontal and five vertical gridlines, like the letter B (De Heij and Koeze, 1987).
Designers should be careful with alterations to characters, as adaptations like shadows, additional outlines and 3D-effects, usually results in a lower legibility, just like the serifs do. The numerals shown in figure 3.8b and c do not only have an outline, they are also designed in different colours, which is suboptimal for instant value recognition, the subject of the last topic within this subsection.

5. Colour of the numeral

The *Stroop-effect* predicts that the process of value recognition will slow down when a numeral is printed in another colour than the banknote (Stroop, 1935; De Heij, 2009). This implies that the colours of numerals should match the main colour of the banknote. A numeral showing two or even three colours will reduce the reading speed (figure 3.8b and c). Numerals on two recent US denominations are not in printed in the colours of the note, which are black (front) or green (back), but in purple (figure 3.5c) and orange (figure 3.5d).

Summarising, the following user requirements are relevant to the design of the numerals on a banknote:

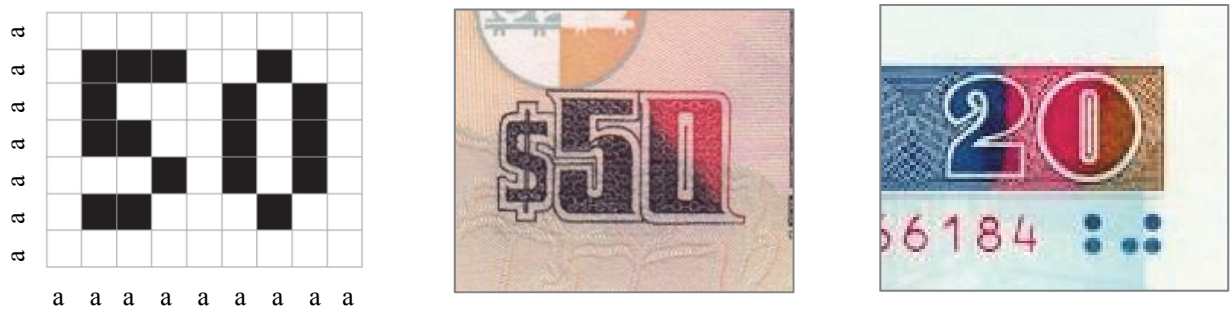
1) Numeral height > 22 mm,
2) Numerals should appear both in positive and in negative,
3) The Print Contrast Ratio > 75 %,
4) Numerals should be printed in the main colour of the front of the note,
5) No serifs, outlines or shadows.

3.2.3 Colours

Colours on banknotes were introduced in the second half of the 19th century. Up to then, the front was printed in specific black inks, which were more secure (McCabe, 2016). The reverse was usually left unprinted (Schell, 2007).
A coloured reverse was introduced as an additional measure to protect banknotes from being mimicked. The public responded to the coloured back of the black banknotes by giving these notes nick names. The design of a Dutch 1,000 gulden banknote issued in 1859 was called *red back*, in Dutch "rode rug" (figure 3.9a and b). In the US, the public reacted in 1862 in a similar way to the green reverse of the one US dollar (figure 3.9c and d) ang *green back* is still a synonym for the US currency. These nick names are one of the first examples of public feedback on banknote design.

Numeral design

Basic numeral 50 | Numeral in 2 colours | Numeral in 3 colours



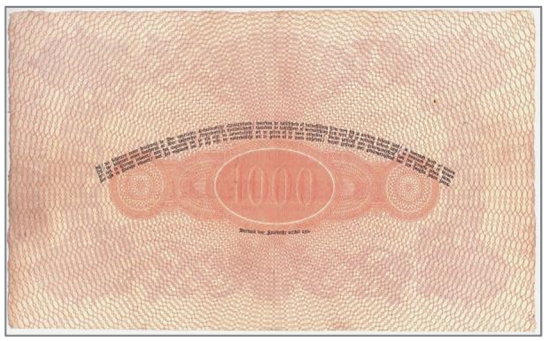
a) b) c)

Figure 3.8
Typographic aspects of numerals.
a) Basic principle of a font type.
b) Belize: two colours for the numeral 50 on the reverse of the BZD 50 (issued in 2010).
c) Cuba: three colours for the numeral 20 on the front of the convertible peso CUC 20 (issued in 1994).

Reverse printed in colour

Black front (1859) | Red back

a)



b)

c)

d)

Black front (1862) | Green back

Figure 3.9
Printed reverse sides.
a) Netherlands: NLG 1,000/Relief Border, issued in 1859. Front: intaglio and letterpress.
b) Reverse: red, letterpress with guilloches.
c) USA: USD 1, issued in 1862. Front: intaglio and letterpress and text.
d) USA: green, letterpress with guilloches and text. Text reads: “This note is a legal tender for all debts public and private except duties on imports and interest on the public debt; and is receivable in payment of all loans made to the United States”.

Colours of banknotes are important and even after a colour change, people may refer to a denomination by its historic colour, like in case of the Dutch 1,000 gulden. The red colour of this banknote model was in 1921 replaced by grey and later by green, but the Dutch kept red back as synonym for an amount of 1,000 gulden. One more example is the 25 gulden, a denomination issued in 1862 with a yellow front and received the nickname *little yellow one* (in Dutch "geeltje"). When this denomination became red in 1921, the Dutch kept using little yellow one as synonym for an amount of 25 gulden. Both nicknames disappeared after the introduction of the euro in 2002, as units of 25 and 1,000 were not part of the euro series.

It is not only nicknames that underline the importance of colours of banknotes, also studies report that colours are a top of mind design element, at least to the Dutch. Bi-annual studies done since the early 1980s consistently report that colour is the best recalled design feature of both guilder banknotes (1983-2002) and euro banknotes (2002-2017) (De Heij, 2006a; Klöne and Zondervan, 2017). These measurements indicate that people associate the colours of banknotes to their value. All 10 guilder banknotes issued since 1904 have been blue, priming 'blue is 10 and 10 is blue'. In 2002, the euro was introduced and the Dutch adapted without problems to the colour changes of their denominations, from then on 'red is 10 and 10 is red'.

Another property of colour is its brightness and people seem to be sensitive to changes in the brightness of banknotes. Brighter colours are usually associated with the front of a banknote. Therefore, the colours of a banknote's reverse are usually less saturated.
The Dutch experienced the euro as being *less* bright than the gulden banknotes (De Heij, 2002a; 2007). People may also notice an *increase* in brightness, as was the case for a new series of Canadian banknotes in 2001; the change most frequently mentioned (34 %) was the introduced brighter colours (Setlakwe and DiNunzio, 2004).
When the first two models of the Europa Series were introduced in the Netherlands, the Dutch were asked about differences between the old and the new euro banknotes. More than half of the respondents (53 %) answered that the colours had changed (Randsdorp and Zondervan, 2015). More information on the perceived changes between the two series of euro banknotes will be provided in subsection 6.2.1.

The origin of the colour scheme of a series of banknotes is often historical and, from a use-centered design perspective, usually a suboptimal one.
A colour circle is a helpful starting point to determine the colours for a series of banknotes. Colour circles may be constructed by applying different principles, like physics, applied by Isaac Newton (1643-1727), or poetry as done by in 1810 by Johann Wolfgang von Goethe (1749-1832). Colour circles for designers were worked out by Johannes Itten (1888-1967), a Swiss expressionist painter and designer associated with the Bauhaus (Itten, 1961).
Attributing different denominations to a colour circle (figure 3.10a) should be done following two basic principles (De Heij, 2000; 2007; 2009):

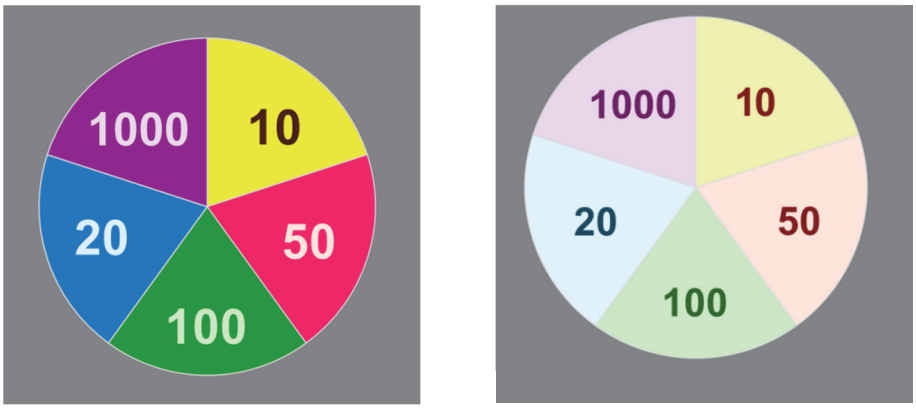
1) Consecutive denominations, like 10 and 20, should have a clear colour difference, so that people will see the difference between these denominations when they are next to each other in their wallet.
2) Denominations having one or more digits in common, like 10 and 100, should not be contiguous in the colour wheel; people may mix up the two when such colours are too close to each other.

Following the colour scheme by Itten, the primary colours yellow, magenta and blue are attributed to a random set of ATM-notes, for example 10, 20 and 50 (figure 3.2). The secondary colours (green, orange and purple) are reserved for the higher denominations, e.g. 100, 200 and 500. Since the human eye is most sensitive to green, this secondary (printing) colour is well chosen for the 100. This leaves purple for the highest denomination, a good choice, as purple in the western world is associated with dignitaries.

Colour circles

Banknote colour
Negative numerals

Background tint
Positive numerals



a) b)

Figure 3.10
Principle of basic colour selection for a series of banknotes.
a) Colour wheel for main banknote colours and negative numerals (except 10, yellow), applied for the MAX-series as shown on the cover of this thesis.
b) Colour wheel for background tints and positive numerals.

Suboptimal colour schemes

Canada, 2007 Dowling Duncan, 2009 Malaysia, 2012

a) b) c)

Figure 3.11
Three examples of series.
a) Canada (2001). Suboptimal consecutive: 5 and 10. Image: Canadian Bank Note Company.
b) US banknote designs by Dowling Duncan (2010). Suboptimal 1 and 5, 10 and 20, 50 and 100. Suboptimal numerals 5 and 50, 10 and 100. Image: Dowling Duncan.
c) Malaysia (2012). Suboptimal consecutive: 1 and 5, 10 and 20, 50 and 100. Suboptimal numerals: 1 and 100, 5 and 50, 10 and 20. Image: Sinar Harian.

Numerals should be printed both in negative and positive (subsection 3.2.2). Negative numerals can be printed by keeping the numeral free from print. The colour of this printed area should be like the main colour of the banknote. A negative numeral can also be printed on a light tinted background, for example, tinted paper, illustrated by figure 3.10b.
Once the colour scheme has been constructed, the colour impression of the individual banknotes should be monochrome and vivid, although a second non-dominant colour may be added. Adding white (pastel tints) or black (brown, olive green) should be avoided (De Heij, 2009).

The identified design principals for the colours of a series of banknotes were applied in the author's proposal for the colour scheme of the euro banknotes (De Heij, 2000; 2007; 2009). The proposal was presented to the "Theme Selection Adivsory Group" by its Dutch member, Jaap Bolten (Heinonen, 2015, page 59).
The colour circle of Itten provides six colours against a grey background, corresponding with seven euro denominations. The denomination at the note-coin boundary received a grey colour, as it will be the first to be replaced by a coin. The colour scheme will remain intact and can be used for a longer period. A grey colour would also fit in an *anti-soil design* principle (subsection 4.6.1). Although optimal for the users, the original proposal was changed by the design management of the first series of euro banknotes. Yellow for the 50 euro, so argued the involved banknote printers, is unusual and difficult to print. In the final proposal the colours of the 50 and 200 were switched, an example of a technology-driven design policy, as in the final colour scheme two consecutive denominations, respectively the 100 and 200 euro, are next to each other, which was not the case in the original proposal.
A further development of this proposal is shown in figure 3.10, allowing numerals to be positive or negative. Such principles could be applied to the colour scheme for the third series of euro banknotes (ES3), which can be revised, as the euro 500 will no longer be part of the series (subsection 2.4.3). One of the options is to make the euro 50 for future euro banknote series yellow instead of brown and to design a purple 200.

Attributing colours to a series of banknotes is often suboptimal from the perspective of recognising value, illustrated by the three examples provided in figure 3.11.

3.2.4 Main images

Alexander the Great (356-323 BC) was - after he had passed away - the first to be portrayed on a coin, a piece brought in circulation around 320 BC. Early banknotes did not carry any images, they are characterised by typographic designs (De Heij, 2012; 2017a). As far as known, the first image on a banknote appeared in 1772 on a Scottish banknote, a portrait; figure 5.15a displays an image of such a Scottish banknote issued in 1777.
Images on the first banknotes were often all the same, like on the first French banknotes. Variety was introduced later, resulting in different main images within a series (subsection 5.5.4).
In the 1970s, the Bank of England conducted a dedicated perception research on constructing a banknote, probably the first in its kind. Professor Ivor B. Stilitz was invited to provide an advice. The study itself remained unpublished (Collins et al., 1985), but a summary of this study has been made public (De Heij, 2007). Stilitz advised small differences between the denominations. Within a fixed basic layout people will notice differences between genuine and counterfeited banknotes more easily, was the basic thought. Stilitz's advices were applied in 1990 within the design of the first model of the E-series (figure 3.12a). The designs were not tested by future users and when in 1991 the second denomination was brought into circulation (figure 3.12c), the public complained about the poor legibility of these notes. In this context of poor legible numerals, it is remarkable that these notes introduced special geometric design elements to assist denomination recognition by the partially sighted (De Heij, 2009).

Similar portraits

a)

b)

c)

d)

Figure 3.12
GBP banknotes E-series, characterised by similar portraits and small denomination numerals. On the left side of the watermark identification marks for poor sighted are designed, respectively a circle, diamond, square and triangle. Designer: Harry Eccleston (1923-2010).
a) GBP 5, issued in 1990.
b) GBP 10, issued in 1992.
c) GBP 20, issued in 1991.
d) GBP 50, issued in 1994.

Four user sub groups

Normal vision

Colour blind (deuteranope)

a)

b)

c)

d)

Partially sighted

Blind

Figure 3.13
Four different visual perceptions of a banknote of 50 euro.
a) Normal vision.
b) Colour blind. The simulated image is representative for the largest group of colour blind, to deuteranopes, i.e. people unable to perceive green-red colours. Image by Blind Color (Van Goor, 2002).
c) Partially sighted. The simulated image is a blurred image.
d) Blind. The part on the right symbolises that blind may have some limited vision. Totally blind will not see anything at all.

In principle Stilitz assumption was confirmed by Masuda et al. (2015); when the differences between the components of a series are small, people need more time to observe the notes. However, the British people preferred optimal value recognition (UIF 1) over an authenticity check (UIF 3), supporting evidence for the ranking of the UIFs within the Model of Use-centered Design of Payment Instruments (figure 2.11).

3.2.5 Visually impaired

The determination of a banknote's value is difficult for visually impaired people (De Heij, 2009). A *normal sighted* person will see a 50-euro banknote as shown in figure 3.13a. To a partially *colour blind* person this note will appear less bright, but will still be sharp (figure 3.13b), while a *partially sighted* person might see nothing but a brown hue (figure 3.13c). *Blind* persons may have some vision left and may see a part of a banknote, schematically indicated in figure 3.13d. When visually impaired can determine the banknote's value, normally sighted are able to do so too, so is the leading thought.

With aging populations, it is expected that the number of partially sighted will increase.
The largest subgroup of the visually impaired are the colour blind. The term colour blindness is a well-established misnomer. The clinical term is "defective colour vision" and is experienced as a mild disability, the reason why this group is usually not part of statistics on visually impaired. Colour blind account for around 4.2 % of the population (Walraven, 2003). Colour blindness is unevenly distributed between the genders: in general, about 8 % of the male is colour blind and 0.4 % of the female.
There are eight classes of defective colour vision, not all of which are discussed here. Most colour blind (75%) have three photo pigments, just as people with normal vision, but one of these pigments does not function properly in either green (about 85 %, deuteranomaly) or red (about 15 %, protanomaly).
The second group of colour blind (25 %) are also identified by their green and red photo pigments. In this case of dichromacy, people miss one of these photo pigments completely (about 55 % of these colour blind miss green, named deuteranope, and about 45 % of these colour blind miss red, named protanope).
Monochromats are truly colour blind and are only able to discern shades of black, grey and white. Complete colour blindness or monochromacy is rare, about 0.1 % of the colour blind.

The interest of central banks for people with defective colour vision dates back to the 1980s, when the Bank of England concluded that "Because of the number of different categories of colour blindness, there is no simple solution to the problem" (study reported in De Heij, 2009). Colour blind were still not covered in a dedicated American study published in 1997, since "no relevant documents could be found" (National Research Council, 1995). Banknotes should be monochrome to accommodate the colour blind, rather than polychrome, so was the only guidance banknote designers relied on.
With the introduction of a colour blindness simulator in 1997 it became possible for people with normal vision to see what the colour blind see (Walraven and Alferdinck, 1997) and the banknotes of Israel were researched with such a simulator (study reported in De Heij, 2009). Such a simulator was also used in January 2002 to create awareness of the perception of euro banknotes by the colour blind (Van Goor, 2002).
Partially sighted are defined by clearness of vision or visual acuity (Snellen, 1862). Literature is available on eye health, like visual impairment, low vision, blindness and legal blindness (Resnikoff et al., 2004). In general, the perception of poor sighted can be mimicked by blurring a banknote, as done in figure 3.13c.
According to the World Health Organization (WHO) a person is "totally blind" when they have no vision, no light perception at all. A blind person is "functionally blind" when, with the best possible correction, their visual acuity is less than 6/60 m and/or their visual field is no more than 20°. Many nations recognise people as "legally blind", often following the definition of the WHO for the functionally blind. A difference is frequently made between the so called "late blind" and the "early blind". Usually the criterion to discriminate between late and early blind is set at an age of four years.

People are born blind, others become blind by disease or accidents. In developed countries, the leading causes of low vision and blindness are diseases that are common in old age, like cataract, glaucoma, age-related macular degeneration, corneal opacities and diabetic retinopathy (Resnikoff et al., 2004). A relatively high percentage of glaucoma patients suffer from this disease due to high blood pressure. Some people who are blind due to diabetes, usually hardly have left hardly any tactile sensation in their fingers.
Obviously, visual design elements are not useful to the blind, they need other solutions. Like others, blind receive their banknotes out of an ATM and they receive payback banknotes at a retailer. Receiving payback notes can be stressful and blind people tend to do their shopping at shopkeepers that they trust. They try to avoid busy hours and may ask somebody to verify the change received. Unlike receiving banknotes, the handover of banknotes by blind persons is relatively easy. At home, they may be partitioning their wallet with different denominations, practised by 60 % of the Dutch blind (Wertheim, 1990). The EBU recommends a wallet with different compartments, storing denominations beginning with the same digit in the same compartment, like one compartment for the 5 and 50, one for the 10 and 100 and one for the 20 and 200 (European Blind Union, 2008). In the US, the advice is to fold dollar banknotes in meaningful quadrants, by folding the notes 2, 3 or 4 times (American Foundation for Blind Vision, 2004).
A summary of the user subgroups and their relevant design parameters for value recognition is presented in figure 3.14.

USER GROUPS AND THE SUB FUNCTIONS OF RECOGNISING VALUE						
User group	**User subgroup**	**User sub subgroup**	**Sub functions of recognising value**			
			1. Colour	2. Main images	3. Large numerals	4. Different sizes
All citizens	1. Normal	-	x	x	x	x
	2. Visually impaired	2.1 Colour blind	s			
		2.2 Poor sighted	s		s	
		2.3. Blind				x

Figure 3.14
User groups and the sub functions of recognising value.
x = in general
s = specific

The following considers features for the blind in more detail.
The National Research Council (1995) published design parameters to prepare an adequate banknote design for the visually impaired. With the announcement of the euro banknotes in 1996, visually impaired provided their user needs, a unique situation (European Blind Union, 1999), unique, because it was probably the first time that user needs related to banknotes were described by the users themselves.
Value recognition by the blind starts with the sizes of the denominations. Up to the 1960s most central banks issued different formats of their denominations, varying both the banknote's length and height. Differences in lengths and height between successive denominations could be as large as 15 mm, large enough for any person to denominate banknotes by its size, including the blind. Over time banknotes' formats were reduced and variable note sizes could no longer serve as a reliable discriminator between different denominations, as will be elaborated on in subsection 3.3.1.
To experience size differences, banknote format schemes should follow Weber's law (1834) that the just-noticeable difference between two stimuli is proportional to the magnitude of the stimuli. Instead of a fixed increment, Weber's law tells that the size differences between banknotes should increase proportional with the length and/or width of the banknote. Weber's rule is often violated, like in the case of the former Dutch gulden coins (Vroon and Wagenaar, 1978).

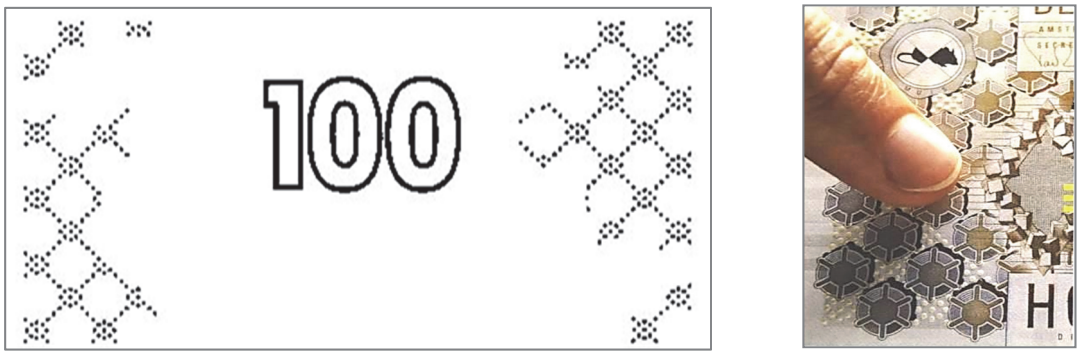
When size differences between banknote denominations do not follow Weber's rule, success rates to distinguish denominations will remain low. As a consequence, small size differences will not be used. Supporting evidence is provided by the two studies mentioned above. Both use comparable stimulus material, the NRC used for their study a set of four substitute banknotes, varying 7 mm in length and 5 mm in height. In case of the EBU, a replica set of euro banknotes was used (seven denominations, varying 6 or 7 mm in length and 5 mm in width, except for the height of the 100, 200 and 500 euro, which is kept similar, in case 82 mm). The success rate for the NRC-study was 90 %, after half an hour learning time. The EBU-study reported success rates varying between 77 % and 94 %. The EBU also reported that most blind only used the length differences of the euro notes.

When the differences in size became too small for a reliable determination of a banknote's value, central banks searched for other design solution. Design solutions for value-identification by the blind are characterised by a history of trial and error (De Heij, 2009). The first was a *tactile mark*, appearing on the front of the Dutch 10-guilder banknote, issued in 1971 (figure 3.5a). This note also offered a length increment of 6 mm between successive denominations, keeping the note height fixed (76 mm). The codification of the marks was set up following a systematic approach. On the 10 gulden three dots were printed, two on the 25 and one dot on the 100 gulden. Marks were not applied to the highest denomination (1,000), because it is found easier to add a mark to a banknote than remove a printed mark, as the ink is firmly attached to the banknote paper. The tactile marks were explained in an early leaflet on banknote features (De Nederlandsche Bank, 1978) and were named tactile marks (in Dutch: voeltekens). In everyday language, these marks for the blind were referred to as "blind marks".
The effectiveness of the tactile marks introduced on Dutch banknotes was assessed in 1988 and proved to be barely tangible, especially on used notes (Koeze, 1990; Wertheim, 1990). As a result, almost half of the blind participants said they never made use of the marks. However, the tactile marks were successful from a public relation point of view; it fitted into the time spirit to do 'something' for handicapped.

Another drawback of the tactile marks was their design, which was too simple, as learned from imitations, part counterfeited NLG 100/De Ruyter (figure 5.16b). The palpability of this dot was mimicked by using the head of a large construction nail; with a slap on the reverse the flat mimicked dot printed was embossed. Although ineffective, tactile marks are still printed on banknotes.
Two more publications appeared on marks for the blind, one reporting on the effectiveness of tactile features in Canadian banknotes (Lederman and Hamilton, 2002) and one reporting on tactile features produced with new, digital plate making techniques for the gravure (Dinse, 2008). New digital engraving techniques made it possible to design higher reliefs and sharper slopes. Furthermore, tactile patterns could be printed up to the edge of a banknote, as will be discussed below.

The results of the study on tactile marks were applied to new designs for gulden banknotes, the first being the NLG 25/Robin (figure 1.2b). Instead of single marks, L-shaped elements were repeated along both short edges (De Heij, 1993; 2009). Blind persons no longer had to search for the right corner of to find the mark, so was the thinking.
The next development was the transition of the repeated L-shapes into a *tactile structure*. Tactile structures are positioned on the short edges of a banknote, the areas were people take a note (subsection 6.3.1). A tactile structure should serve the public as an authenticity feature (feel) and should also be a denomination code to the blind. Figure 3.15a shows the first, a dot structure for the NLG 100/Little Owl. The tactile areas are positioned away from the note's edge, where wear and tear will disturb the tactile perception. Furthermore, the structures are printed in a transparent ink, reducing its visibility and delivering two advantages. First, the design is not disturbed by the structure, a 'measles design' is prevented in the case of dots. Second, this approach emphasised the tactility of the structure and not its visibility, appreciated by the blind as this solution was not experienced as stigmatising. The tactilitiy of the dots was well perceptible. Subsequent designs received a similar approach, curved lines (NLG 1,000) and chevrons (NLG 10), all according to a pre-set plan by Jaap Drupsteen (reported in De Heij, 2009).

Tactile structure in NLG 100 (1993)



a) b)

Figure 3.15
Tactile structures with codification.
a) NLG 100/Little Owl, issued in 1993 is the first note with a full tactile structure using dots printed in transparent intaglio. Image: Joh. Enschedé.
b) Detail of NLG 100/Little Owl. Image: Jaap Drupsteen/De Nederlandsche Bank.

Similar line patterns for the blind

Pakistan (2006) Russia (2010)

a)

b)

c)

d)

Hong Kong (2012) Euro (2013)

Figure 3.16
Tactile patterns along the short edge based on stripes are a trend. Although these patterns show similarities, the specifications and the coding system are different for each currency. Such patterns are also printed on banknotes of Argentina, Colombia and Sweden.
a) PKR 500, issued in 2006.
b) RUB 1,000, issued in 2010.
c) HKD 100, issued in 2012.
d) EUR 5, issued in 2013.

The developments of tactile structures on Dutch gulden banknotes were input for the design of the first euro banknotes. A tactile pattern was applied to the long edge at the bottom of the euro 200 and another line pattern along the short edge on the righthand side of the euro 500 (De Heij, 2009). Although the European Blind Union agreed with the proposed sizes and tactile structures, these solutions were later criticised, as the blind do not use these two high denominations; their main interest are the payback denominations (5, 10 and 20 euro), which did not have such tactile patterns. Since 2006, a trend is observed of stripe patterns along the short edge, stripes with a relief (figure 3.16). These patterns are running up to the edge of the banknote, which is made possible by digital techniques for plate engraving, introduced in the early 2000s (CtIP, Computer to Intaglio Plate). The success rates of such stripe patterns have been, as far as known, not researched.
Furthermore, only line patterns are used and should therefore be coded to be able to identify different denominations, a codification which must be learned. This type of tactile line patterns is believed to be suboptimal, as other patterns are not applied (dots, chevrons).

The short and long side of a banknote remain often unused as an information carrier about the denomination, except, as mentioned, for the euro 200 and 500. Two studies report on the advantages of such an approach, a study by De Heij (2009) a recent study by the main producer of gravure ink (Sicpa, 2017). This last study reports on "user-centered banknotes", as "a panel of users participated in individual interviews and usage tests carefully prepared by the design studio". The presented, preliminary results, point in the direction of the tactile patterns, as have been applied in the Dutch Abstract Series, and an alternate position along the short and long side of the denominations.
A study on the preferences of Japanese respondents offered three basic tactile patterns, grids, lines and dots (Fukuda, 2016). The outcome was a preference for line-patterns. This study did not report on the discrimination between different denominations.

Another type of solution to assist the blind to denominate banknotes are tools. The "CashTest" is such a device, introduced in 1992 in several countries, like Austria, Germany and Italy. The euro followed in 2002 and Australia in 2012 (figure 3.17a). The device has the size of a credit card. After inserting a banknote, the note must be bend over the edge into the measuring zone. Subsequently, a finger may 'read' the raised marks on the device, which have a higher relief than can be achieved on banknotes. The marks are made in braille and in simple symbols. The CashTest is only usable if denominations differ in length and will not bring a solution to Canadian and USA banknotes, because these denominations all have similar sizes. In case of uniform banknote sizes, an electronic device may assist the identification by emitting a series of 'beeps' or other signals, which became first available in Canada (Bank of Canada, 1982). Since 1986 barcodes were printed on the denominations, allowing the visually impaired to distinguish notes with the use of a hand-held device that tells the note's denomination. At that time, the Canadian bank was (Melbourne, 2008):

> "(…) under a lot of pressure to make notes readily distinguishable to the visually impaired, particularly to use the favoured method, i.e. different size notes as is the case with many currencies. But studies found that the cost of doing so would be prohibitive to the retail and banking sectors, and so the Bank developed the reader instead."

The "Note teller" was also introduced in the US (figure 3.17b). However, not enough for the American Council of the Blind, demanding the FRS in a law suit for "meaningful access" of the visually impaired to dollar denominations (United States District of Court for the District of Columbia, 2008). For the first-time banknote users sued a central bank to adapt their designs to user needs. In 2011, the continuing development of technology brought a solution, when the "EyeNote App" was made available for free on the iTunes App store (figure 3.17c). The EyeNote App is the first to provide a 'banknote-to-internet-link' to assist with denominating banknotes (UIF 1), as will be elaborated on in subsection 4.7.5.

The previous demonstrated that denominating banknotes by the blind has been object of study. Analysing these studies resulted in a list of user needs as presented in figure 3.18.

3.2.6 Design parameters related to value recognition

The time needed for a payment transaction is an important user criterion (subsection 8.2.3). Applied to a cash transaction, the faster people can tell a banknote's value, the better they are served. Four design elements support the function of recognising value: numerals (1), colour (2), a main image (3) and formats (4). These four design elements can be applied in different orders, as illustrated by the three banknote designs shown in figure 3.19. In the first banknote, the NLG 100/Snipe, the image of a bird prevails over the brown colour (figure 3.19a). When the colour would change, the Dutch would still say: this is the 100-gulden snipe.

As the Dutch recall colour first, the brown colour prevails over the denomination numerals. The second example is the euro (figure 3.19b), a banknote design which is, most likely, first recognised by its colour, subsequently followed by numerals, sizes and main image. The third example is the dollar (figure 3.19c). Although the latest dollar designs show more colour, these colours are probably not dominant over the numerals or the portrait image.
Denominating a banknote, which of the concepts shown in figure 3.19 will serve the user best? When the response time to value recognition is the criterion, the best concept is the one which delivers the shortest response time.

Devices to assist the blind

CashTest
Australia, 2012

Note teller
USA, 2003

EyeNote App
USA, 2011

a) b) c)

Figure 3.17
Impression of devices to assist the blind in denominating banknotes.
a) CashTest device as introduced in Australia in 2012. Image: Reserve Bank of Australia.
b) NoteTeller2 by Brytech introduced in the USA in 2003. Image: US Bureau of Engraving and Printing.
c) EyeNote App by US Bureau of Engraving and Printing (USA, 2011). When the camera of the smartphone has scanned 51 % of the surface of a US dollar banknote it will tell - audibly or by vibrating - the denomination. Audible responses are available in both English and Spanish. The vibrations are coded by one pulse for the USD 1, two pulses for the USD 2 and so on, up to five pulses for the USD 100. To assist when paying at automated vending machines, the app will also tell whether it is the front or back of the note. Image: US Bureau of Engraving and Printing.

User needs Blind	Description
1. Denominating time < 3 s (without a device)	Blind should be able to denomination a banknote within 3 seconds.
2. Confusion error < 1 %	Mixing up denominations should not occur. Responding a wrong value should happen in less than 1 % of the user situations, including value recognition in a dark taxi.
3. Standard position	Denomination features should have a standard, fixed position in the pre-set layout, minimising search tasks.
4. On all denominations	Denomination features should be available on all denominations. Especially the payback notes are of interest.
5. Discretely	Blind should be able to denominate a banknote discretely; blind do not want to attract (additional) attention in a shop.
6. No training needed	Denominating a banknote should be possible without (intensive) training.
7. No assistance needed	Denominating a banknote should be possible without any assistance.
8. General quality of the feature	The general quality of the feature should not be perceived as cheap or as poor quality.
9. Long-wearing, remains readable	The general quality of the feature used should remain; the feature should also be effective to denominate unfit notes.
10. Difficult to simulate	Although not a security feature, denomination features for the blind should be difficult to simulate.
11. No additional device needed	Denominating a banknote should be possible without any tool or device. Additional time is needed to prepare the tool or device; once ready, the denominating time should be less than 3 seconds.
12. Inexpensive use	Using the feature should be inexpensive. In case of a device, battery consumption should be low (also for reliability reasons; no downtime).
Constraints	
13. Low cost for producer	The additional cost of the feature should not exceed (for example) 1 % of the total production costs of a banknote.
14. Non-destructive to banknote	The feature should be non-destructive to the banknote.

Figure 3.18
The needs of the blind towards value recognition. The items 14-16 are constraints from the side of the central bank.

Design concepts of value recognition

NLG 100/Snipe (1981)	EUR 50/Renaissance (2002)	USD 20/Hamilton (2004)
		
1. Image 2. Colour 3. Numerals 4. Sizes	1. Colour 2. Numerals 3. Sizes 4. Image	1. Numerals 2. Image 3. Colour 4. Sizes
a)	b)	c)

Figure 3.19
An example of varying the sequence of sub-functions of value recognition within three different banknote designs. It is the author's assumption that shortest response time to value recognition will be delivered by the NLG 100/Snipe (a), followed by the EUR 50/Renaissance (b) and the USD 20/Hamilton (c).

3.3 Handling (UIF 2)

Handling is the second User Interface Function (UIF 2), after recognising value (UIF 1).
Handling is a collective term for all kind of manipulations done with banknotes, such as taking banknotes out of an ATM, accepting a banknote from another person, folding the note, storing it and feeding it into automates. People handle banknotes at different locations, under various lightning conditions (subsection 5.2.1), and under various weather conditions (subsection 3.3.2). Handling also covers health and safety topics. A *clean note policy* aims for proper banknotes coming out of an ATM and is also part of the handling function. A clean banknote policy may also contribute to 'keeping confidence' (UXF 3), as it underlines that the central bank is in control of its currency.

In general, consumers put less value on products which have already been touched by others (Argo et al., 2006). Several studies report on the neatness of banknotes, like a study telling that people would rather use clean banknotes, than soiled and/or damaged banknotes (Di Muro and Noseworthy, 2013). Another study reports that the physical appearance of banknotes at offer may affect the perceptions of the person using these notes (Verhaegen, 2014). Such studies were carried out with 5 and 50 euro banknotes and reported that people first spend worn or dirty banknotes. However, the opposite was reported in a publication on an early Dutch banknote circulation trial: "The rate at which banknotes are returned to the Bank appears to be independent of age or deterioration, contrary to the common notion." (Koeze, 1979).
Central banks may follow a *clean note* policy, which is not similar to a *durable banknote policy* aiming for a longer life. Clean banknotes are a public user need, but people are not aware when a worn note is replaced by a fit one. Durable banknotes are a cost parameter to the central bank and may therefore be of influence on the profit of the central bank, which in turn is of influence on the income of the state. Furthermore, durable banknotes will lead to fewer banknotes and will therefore contribute to sustainable banknotes (UXF 5), a relative new user requirement, which will be introduced in more detail in section 4.6.
This section continues with the introduction of the banknote's orientations and dimensions (subsection 3.3.1), followed by an analysis how people receive, store and pay with a banknote (subsection 3.3.2).

3.3.1 Orientations and dimensions

From a geometry perspective, a banknote is a rectangular, defined by a length of *x* mm and a height or *width* of *y* mm. Although the thickness of a banknote is limited, a banknote does have a third dimension, denoted by *z* mm.
Banknotes have a front and a back and for each, a choice should be made for a horizontal or vertical orientation, also known as respectively landscape format or portrait format. These options make that banknotes have four orientations.
This subsection continues with orientation schemes for a single banknote (topic 1), followed by format schemes for a series of banknotes (topic 2) and a review of the sizes of a banknote (topic 3).

1. Four orientation schemes

At the start of a design project, a central bank usually prescribes the denomination scheme and the banknote sizes and leaves the orientation parameter unspecified.
Figure 3.20 unveils four basic schemes to map a banknote. The banknotes represented by scheme A combines a horizontal front and a horizontal reverse. From a user's perspective scheme C is the most attractive scheme. When people take banknotes out of an ATM and store them in their wallet the notes are in a horizontal position (figure 3.21a), while inserting a banknote in a payment terminal the note is in a vertical position (figure 3.21b). Retailers store the received banknotes in the compartments of drawers, often in a vertical position.
When all public authenticity features would be positioned on the front, scheme C would also match with the public's preference of all public features on the front (subsection 6.4.1).

2. Five format schemes within a series

Five different format schemes are provided in figure 3.22 (National Research Council, 1995). The first is scheme A, which keeps all denominations similar in size (figure 3.22a), a common approach for early banknote series, like the gulden series issued in 1814. Varying lengths and widths within a series, scheme B, was introduced around 1850 and was common practice by the year 1900 (figure 3.22b). Designers will experience scaling problems with this scheme, numerals may appear smaller on large denominations, although being similar in height, as one may experience with the numerals of the 5 and 500 euro (De Heij, 2009). Varying the length only, Scheme C, is the preferred option (figure 3.22c), as it serves both automated processing and denominating of banknotes by the blind. No examples are known of format scheme D, varying the height only (figure 3.22d) or scheme E, representing hybrid variants (figure 3.22e).

3. Sizes

Early paper money is large compared to modern banknotes. An example is Chinese paper money, issued between 1375 and 1380, known as Ming dynasty note. This paper money measures about 340 mm x 220 mm, larger than a sheet A4 (Cartwright et al., 2014). Large sizes were no problem, as paper money was mainly used by merchants and not on a daily basis.
Over time banknotes became smaller. In the first half of the 19th century, the size of a common letter was a reference for banknote sizes, for example in Sweden. In the 1940s, Finnish bank cashiers were asked about the smallest size for banknotes that could still be sorted and counted by hand (Heinonen, 2015). Today, the main user criterion is that banknotes should fit properly in people's wallets. Smaller notes better fit, thereby reducing wear and tear. US dollar banknotes fulfill this user requirement since 1929, when all dollar denominations received a note height of 66 mm. Before this decision was made, trials with such sizes were carried out in the Philippines, a colony of the US from 1898-1946. A note height of 66 mm is still appreciated as it fits properly in 'billfold' wallet types, which fits in the pockets of trousers, especially jeans.

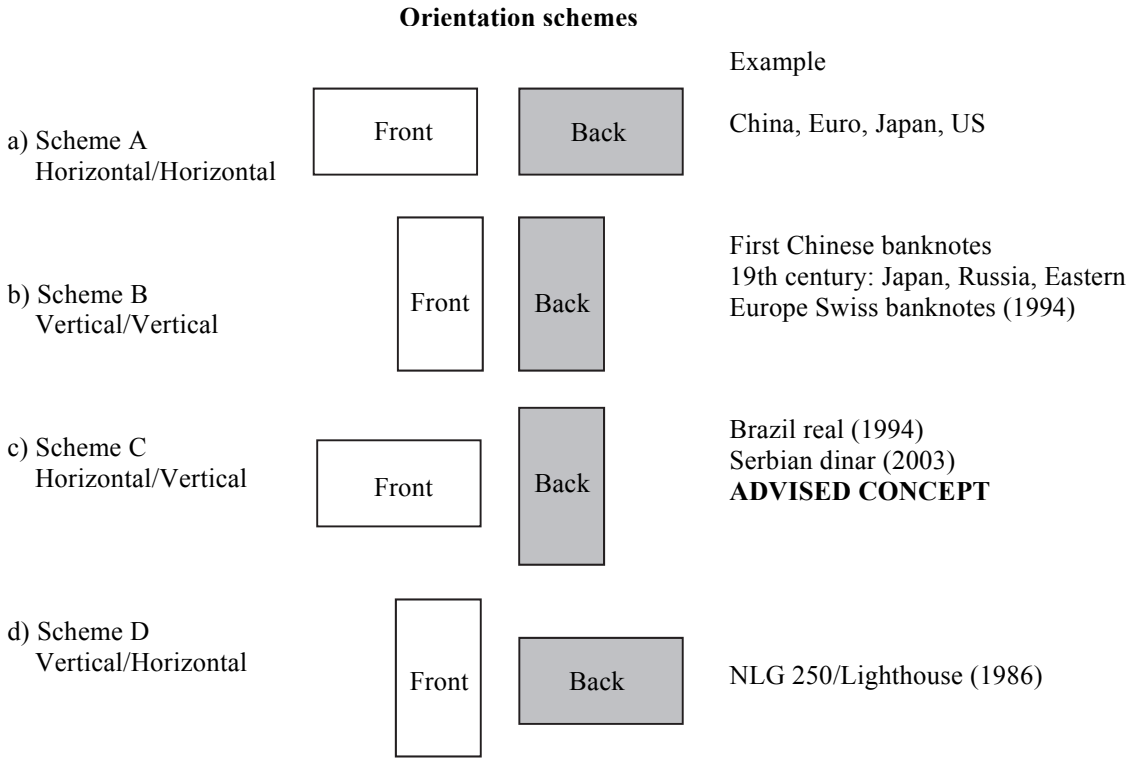


Figure 3.20
Four orientation schemes of a banknote.

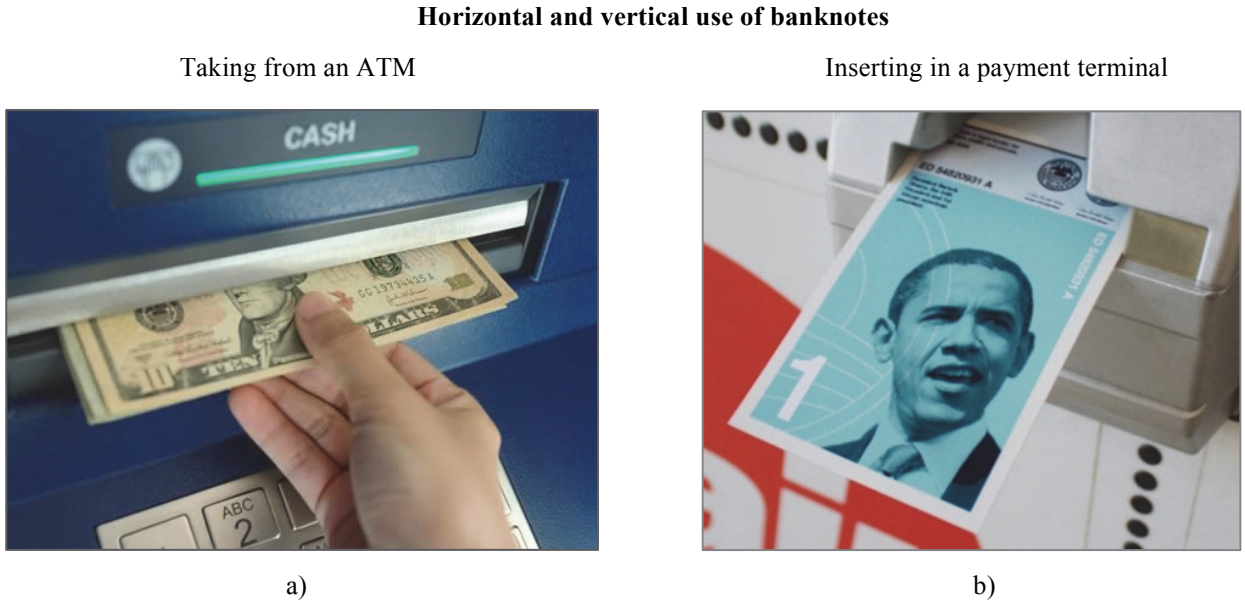


Figure 3.21
Impression of automates providing banknotes and accepting banknotes.
a) Banknotes are taken from an ATM in a horizontal or landscape position. Image: public domain.
b) Banknotes are inserted in a payment terminal accepting banknotes in a vertical or portrait position. Design by Dowling Duncan, 2009.

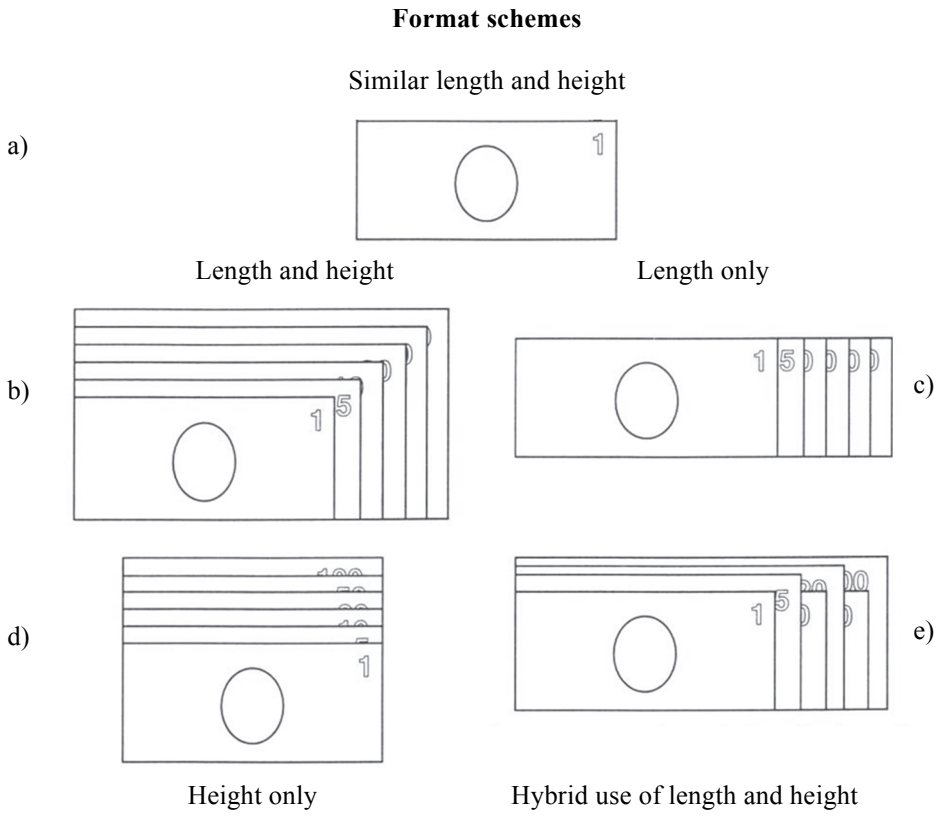


Figure 3.22
Five different schemes for the formats of a series of banknotes (National Research Council, 1995).
a) Scheme A. No variation in size.
b) Scheme B. Varying both length and height, known as tiered sizes.
c) Scheme C. Length variations only. ADVISED CONCEPT.
d) Scheme D. Height variations only.
e) Scheme E. Varying length and height using an alternating small-large sequence.

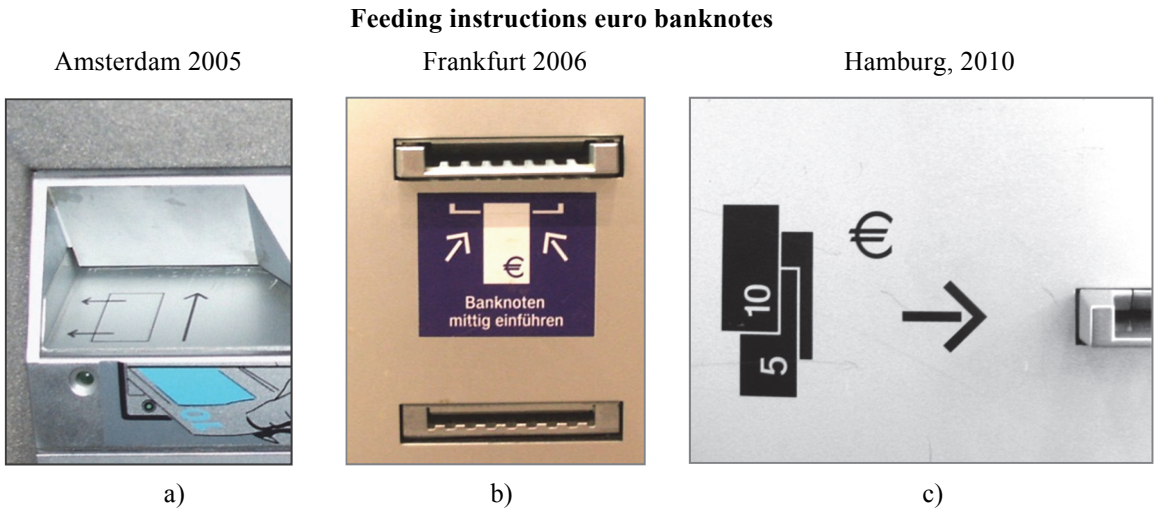


Figure 3.23
Instructions to insert euro banknotes into a machine. All images: De Heij.
a) Push the note forward and at the same time move the note to the left (Amsterdam, subway system, 2005).
b) Additional instructions appeared on the vending machines telling to keep a euro banknote in the middle of the slot when feeding it (*Banknoten mittig einführen*) (Frankfurt, public transport system, 2006).
c) Feeding instruction of euro banknotes on a ticket automate (Hamburg, railroads, 2010).

A single note height was also introduced by other central banks, like in Honduras in 1939 (68 mm), in Costa Rica in 1939 (67 mm), and in 1954 in Canada (70 mm) and Finland (69 mm).
When modern banknotes are too large, exceeding a height of 75 mm, they tend to stick out of wallets. Over the decades, the length of banknotes have also been reduced, like the reduction of the maximum length of Swiss banknotes from 181 mm (CHF 1,000) to 158 mm (Swiss National Bank, 2005).
A banknote length of 130 mm is perceived as too small (Abrams, 1995). Such small notes look cheap, so was the opinion of the respondents, all employees of the International Monetary Fund (IMF).

It is not only the user who benefits from usable banknote formats, also the central banks will profit. First, the banknote production costs will decline. Banknote paper is paid per kilo and with lighter banknotes there will be more banknotes within one kilo. Also, the printing efficiency can be increased when smaller banknotes have to be printed, as more banknotes can be accommodated on one sheet. Second, when banknotes fit better into people's wallets, the bank has fewer banknotes to replace. Formulated by the Bank of Israel in 1999 on the occasion of the introduction of their new banknotes as follows (Bank of Israel, 1999): “They are narrower than the first NIS series so that they do not protrude from the average size wallet, thereby reducing wear and tear”. A similar statement is made by the Swiss central bank, when the note height was decreased from 74 mm to 70 mm (Swiss National Bank, 2005): “With their proportions being more ideal, the banknotes will not only give a more favourable overall impression, but wear and tear in the wallet can also be reduced”. The smallest length in the series of Swiss banknotes is 123 mm (CHF 10), which makes Abrams’ criterion of 130 mm disputable. Euro 5 banknotes are even smaller, measuring 120 mm x 62 mm.
Up to the 1970s, central banks sorted banknotes by hand. The introduction of *mechanisation* of banknote sorting processes replaced hand sorting. To operate such machines more efficiently a single note height was introduced. In 1970, the Dutch central bank was, as far as known, the first to introduce a length difference of 6 mm between successive denominations (scheme C, figure 3.20c), serving the mechanical sorting process, but also offering a feature for value recognition to the blind. In the 1980s, the *automation* of banknote sorting machines took off, starting with transporting banknotes at a speed of 4 m/s and in this stage of the development of banknote sorting machines, central banks followed the approach of the Dutch central bank. For example, in 1980, the central bank of Belgium combined a single note height with a length difference between successive denominations, and others followed later (De Heij, 2006b).
In the 1990s, central banks replaced the banknote sorting machines by high speed machines, running up to 10 m/s. At that time, automated processing appeared also in other parts of the cash cycle of banknotes, like the large-scale introduction of ATMs and payment terminals suitable for banknotes.
A length increment of 6 mm between successive denominations was experienced as small, as suboptimal. This was also caused by the cutting tolerances of +/- 1 mm for each edge. Sizes differences in length could therefore be smaller than 6 mm (De Heij, 1989c). Several central banks opted therefore for larger length increments. In 1992, Banque de France introduced a length increment of 10 mm for their series. In 1994, Swiss banknotes received an increment of 11 mm, the largest within modern banknotes. In 1997, the Danes introduced an increment of 10 mm for their series. Since then, length differences between banknote denominations have been reduced and today a common length difference is 7 mm or 8 mm.

Format scheme B (figure 3.22b) was a popular scheme, known as *tiered sizes*, varying denominations both in length and width. This format scheme has become outdated as it complicates the feeding of banknotes into automates, illustrated by the examples provided in figure 3.23. A standard note height would simplify feeding instructions to a mere: push the note forward.
Another relevant parameter to the users of a banknote automate is the distance between the instruction screen and the slot for the banknote (Verhoef, 2007), a parameter which, according to Verhoef, can also be improved on user-friendliness.

Euro banknotes have tiered sizes and the introduction of the euro made that a single note height disappeared in Belgium, France and the Netherlands. The dimensions of euro banknotes were subject of study in the Netherlands, with the outcome that people preferred the size of the euro 20 (the findings are reported in subsection 6.3.1).

One of the Dutch stakeholders on banknotes, the Netherlands Bankers Associations, recommended the (re)introduction of a standard banknote height (Nederlandse Vereniging van Banken (2005); the advice is reported in De Heij, 2009). However, the dimensions of the euro denominations of the Europa Series, of which the first model was issued in 2013, remained unchanged. The future denominations of 100 and 200 euro will be made smaller, the height will be reduced from 82 mm to 77 mm, the same as the euro 50. As reported in subsection 2.4.3, the euro 500 will not be part of the Europa Series.
The central banks of Sweden and Norway introduced a single note height respectively in 2016 and 2017. The Bank of England announced in their new banknote series "The existing format of tiered sizing will be maintained, i.e. the higher the denomination, the longer the height and the length of note." (Bank of England, 2016).

3.3.2 Receiving, storing and paying

This section follows people's logistics when handling a banknote. A banknote is first received (topic 1), subsequently stored for some time in a device (topic 2), before the banknote is used for a payment (topic 3).

1. Receiving a banknote

People receive a banknote from an ATM or from another person. The notes from an ATM are usually offered in a *static* and horizontal position (figure 3.21a). When a banknote is handed over from one person to another, this is usually in *motion.* Furthermore, the note is offered under an angle, somewhere in between a fully horizontal position (0 degrees) and a fully vertical position (180 degrees). As a result, the first impression of a banknote is a rather blurred image in a distorted position. In such situations, the banknote's colour will be the main information to the receiver (subsection 5.2.1).
Most receivers will take a note with their right hand, as a variety of studies suggest that 70 % to 90% of the world population is right-handed, rather than left-handed (Johnston et al., 2009). Many people are ambidextrous and can use both hands for a cash payment. Therefore, left-handed persons may also take a banknote with their right hand, as this is a common politeness rule. Once people take the banknote, there will be a combined effect of vision and touch, a case of multi-sensory input (section 5.2).
In another payment situation people insert a banknote in a vertical position into a payment terminal (figure 3.21b). Once more, most people will insert the note with their right hand.

2. Storing a banknote

Once people have received a banknote, they will store it in a storage device, like a wallet. Traditional *cash wallets* have been replaced by other devices. Today people may store one or two banknotes in a *card case* (figure 3.24a) or in a *smartphone case* (figure 3.24b).
The size of a card is standardised (ISO, 2003; ISO, 2006): (length) x (height) x (thickness) = 85.60 mm x 53.98 mm x 0.76 mm. This 'credit card format' may influence the future sizes of banknotes. Folded in four, the sizes should be proportional to the card format, indicating that the height of future banknotes should be maximal 80 mm.

People may keep a banknote in different places, like a wallet or a swimsuit. Kept in a swimsuit, people expect that the banknote will not fall apart like a newspaper does. A banknote should not irritate the skin and it should be safe to clamp a banknote temporally between the lips. Such health and safety factors are part of the *basic user requirements of a banknote*, requirements which are independent of the design. These types of user requirements are introduced as follows: health and safety issues (item a), household accidents (item b), cultural habits (item c) and climate (item d). A condensed overview of the basic user requirements of banknotes, independent of their design, is provided in figure 3.25.

a. Health and safety issues

A strong normative belief is 'Money is dirty'. Parents tell their children: 'Do not put money in your mouth'. Indeed, people don't want to become sick of using banknotes. It is not just the notes which can be dirty, the ATM can also be filthy. Dirty keys or a dirty screen when entering their PIN-code will not be appreciated by its users (figure 8.5b).
Two situations are relevant to central banks to manage health and safety issues of banknotes, its production and its circulation.

Modern wallet use

Banknotes in card case

a)

Banknotes in a smartphone case

b)

Figure 3.24
a) Metal card case by Troika (2017). Special clip to hold banknotes.
b) Leather smartphone case by GSMWise (2017). Banknotes are stored in a sleeve behind the cards.

When it comes to health and safety, banknotes may be compared to the doorknobs of public buildings or the poles in public transport. Toys can also be a reference for health and safety regulations of banknotes, as was the case for the ingredients of Dutch banknotes in the 1990s. The safety risks concerning banknotes are covered by "Safety Data Sheets", to be provided by paper makers and printers, who, in turn, required such sheets from their semi-finished product suppliers. Banknotes should be printed with non-toxic inks; cadmium and carcinogenic compounds were banned. In 1993, at the time of the development of the NLG 1,000 /Lapwing, DNB asked their printer Joh. Enschedé to do an additional study on the materials applied (Heeremans, 1995). In absence of any specific regulations, an independent institute was asked for advice on health and safety aspects of banknotes, including liability and environmental aspects (Bosman, 1996). This type of testing was developed further for the NLG 10/Kingfisher, issued in 1997, including an acute oral toxicity test, a dermal irritation test and a bacterial reverse mutation test (Prinsen and Van Delft, 1997).
In 1998, the developed test procedure was adopted for testing the first euro 200 banknote production, a responsibility of DNB on behalf of the Eurosystem (Prinsen and Van Delft, 1999). Subsequently all euro denominations were tested following this method, which made it possible for the ECB to publish that all suspicious substances remained below the legal limits as applicable to foodstuffs or day-to-day products in contact with the human body (European Central Bank, 2012).
Health and safety regulations for the production process of banknotes are laid down in ISO (2016).

Once banknotes have been produced, they will be brought into circulation, where they encounter pathogens, anything that can produce a disease. In 1972, the American Medical Association identified for the first time the presence of bacteria on the surface of banknotes. Since then various studies revealed the presence of bacteria, fungi and other potentially harmful or infectious contaminants. The two most notorious families of bacteria widely found on banknotes are e-coli and staphylococcus.

User requirements **Basic usage - design independent (UIF 2)**			
Critical	**User requirement**		**Test prescription**
Public	**1. Banknotes should not hurt people (health and safety).**		
	1.1	Taking a banknote in mouth.	Like regulations of toys for children. Non-toxic (e.g. no hexavalent chromium).
	1.2	Not transfer diseases.	Killers or inhibitors: bacteria, viruses. Food may encounter cash (hygiene in bakery and butcher). Blood may encounter banknotes.
	1.3	Not be irritating to the skin	No elements from standard lists (like nickel).
	1.4	No escaping solvents, no smells	Evaporation test.
	2. Banknotes should resist household accidents.		
	2.1	Chemically durable, resistant to - Water, - Acetone, - Alcohols, - Caustic soda.	 - 5 minutes in boiling water. - 5 minutes in 60 % solution of acetone. - 5 minutes in 60 % solution of alcohol. - 5 minutes in 60 % solution of caustic soda.
	2.2	Mechanically durable, resistant to - Tearing, - Tensile, - Abrasion, - Scratching.	 - Tearing resistance > 1,400 mN. - Tensile strength dry > 110 N. - Abrasion test. - Scratch test.
	2.3	Remains one piece, also after washing, indelible.	Put banknote in a washcloth and wash on standard programme.
	2.4	Ironing.	60 C, 30 s.
	2.5	Heating in a microwave oven.	Medium power, 60 s.
	3. Daily life, notes should stay neat.		
	3.1	Banknotes should not stick together.	Put pressure on pile of banknotes.
	3.2	Be foldable, repeatedly.	Double folding MD > 800, CD > 1,000.
	3.3	Not fall apart in the rain.	Tensile strength wet should be > 30 % of dry.
	3.4	Should resist sunlight (e.g. on car dashboards).	Colour fastness, BW > 6.
	3.5	Heath resistant (e.g. radiators)	Resist temperatures up to 375 K (~ 100 C)
	3.6	Should resist coffee, beer	Anti-soiling properties, like e.g. the coffee test
	4. Banknotes should be optimised for climate conditions		
	4.1	Banknotes should not absorb humidity.	Synthetic substrates in tropical, humid climates.

Figure 3.25
Basic usage requirements of a banknote.

Viral contamination of banknotes usually reduces within 24 hours to negligible levels. The situation is different for warm and humid climates, which are an ideal environment for fungal growth.
Riemann (2014) provided an overview of studies done on micro-organisms on banknotes, which may spread from one individual to another. In general, micro-organisms have a short life on a banknote, so is Riemann's conclusion.

b. Household accidents

People carry banknotes to their homes, where all sorts of 'household accidents' may occur. A banknote may be left behind in one of the pockets of a trouser and may accidentally end up in the washing machine. People will unfold the washed note and may even iron it. A banknote may fall in a swimming pool, or tea, coffee or beer may be spilled on them, banknotes may even be cooked. People may keep banknotes in a micro wave oven. People may also 'test' banknotes intentionally with solvents, such as acetone or other daily products stored in the bathroom or kitchen cupboard. Banknotes can be used to take drugs. People may draw moustaches or other things on banknotes and they may even hold a lighter to a banknote. Kept in damp rooms, banknotes may stick together, which may also happen when notes are stored underground.
Central banks have their banknotes tested on the resistance to such household accidents, usually carried out at the laboratory of the printing works (De Heij, 2008c). Standardised test instructions usually indicate that a sample has a certain size, for example a strip or a square. However, testing of complete banknotes is preferred.

c. Cultural

Handling banknotes is culturally determined. People may carry banknotes in wallets (e.g. in the Netherlands) or keep them in their pockets together with some coins (e.g. Ireland). Banknotes may also be kept as bundle, often hold together by a metal clip (e.g. Mexico). Cultural differences also come in when banknotes are folded in two (e.g. Europe), three (e.g. USA) or even four or more parts to fit in small purses. A specific category of folding habits are variants of origami, complex folded banknotes given on special celebrations (e.g. China, Japan).

d. Climate

Banknotes are traditionally made of natural fibres, usually cotton fibres. Synthetic substrates arrived in the 1960s, but were not yet applied for banknotes. Nowadays, the local climate may influence a central bank's decision on the type of substrate and varnish. Traditionally, banknotes were produced to be used in mild climates, one of the five climate categories as first introduced in 1884 by Köppen and Geiger (1936). The other four are tropical, dry, continental and polar climates. As bacteria may grow rapidly in hot and humid conditions, 'plastic banknotes', with a closed surface are more suitable for tropical, humid climates than paper substrates, which have a more open surface. Subsection 4.6.1 elaborates in more detail on synthetic substrates.

3. Paying with a banknote

A study has been done on *taking* a banknote (topic 1), but no studies seem to have been carried out on a person *handing over* a banknote to another person or a machine.
Paying with a banknote starts with selecting one or more banknotes out of the storage device, usually a wallet. Looking in their wallet, people will only see a part of their banknote(s). Banknotes signal their function of recognising value; looking for a 20-euro banknote to pay with, people will recall that it is blue and start searching for blue, ignoring other colours. Once the banknotes have been retrieved, people will verify if the right value has been selected and they may check whether notes are sticking together.
Banknotes are kept in a wallet and to the Dutch banknote designer Jaap Drupsteen, introduced in section 1.1, this was a reason to have both colour and 'denomination grid' running to all four borders (figure 1.2). Seeing any small edge, people would know the denomination, so was Drupsteen's leading design principle (Bolten, 1999; De Heij, 2012).

There is no common way of how a banknote should be fed into a banknote payment terminal. Feeding a banknote into a machine can be complex, involving the following four steps. First the user must find out how the banknote must be inserted, by feeding the long edge or the short edge? In a second step, the user must determine whether the front face should be up or down. And third, it should be clear whether the top or the bottom should go first into the slot opening of the machine. Finally, the banknote should, when feeding, be guided to the left or to the right of the slot opening. A new banknote is more easily inserted into the slot than a limp or folded banknote. In general, people are willing to smoothen a banknote, like unfolding clipped corners (dog ears).
A rejected banknote will make the user insecure and as a reaction the user may try to re-insert the note again, but this time in a different orientation. With all banknotes having a similar note height (subsection 3.3.1), notes would be less likely to skew and the undue return, known as rejects, will be reduced. Second, banknote designs could show a clear, natural feeding direction. A feeding arrow has been proposed to assist, reassuring the proper feeding direction (De Heij, 2007). Third, the central bank should follow a tight Quality Assurance, focussing on narrow production tolerances, as this will reduce the reject rate of banknotes offered to a machine.

3.4 Checking authenticity (UIF 3)

After value recognition (UIF 1) and handling (UIF 2), a banknote's third User Interface Function is checking authenticity (UIF 3). It was - and still is - natural for central banks to turn their attention on new authenticity features, as banknotes should be protected against new reproduction threats. However, to the public, this user function is of less interest than UIF1 and 2 (figure 2.16); people don't use banknotes to check them on authenticity.
Coins were mainly authenticated by their weight. With the arrival of paper money merchants wanted to be able to verify the authenticity of paper money, the argument to introduce authenticity features. Early banknotes carried about five of such features, while modern banknotes may include over 35.
In the past, central banks did not inform the public on authenticity features. To tell the public was to inform the counterfeiter, so was the reigning thought. Cashiers of commercial banks, the post and railways, and other stakeholders were informed about the features of a new banknote. When in 1976 the Swiss introduced the first information leaflets on explaining authenticity features for public use, the existing policy started to shift (Swiss National Bank, 1976). The new policy was - and still is - to involve the public as a 'first line of defence' against the spread of counterfeited banknotes. After the Swiss, others followed. In 1986, in the Netherlands an information leaflet, aiming at the public at large, accompanied the issuance of the NLG 250/Lighthouse. The design of this folder was based on an experimental leaflet prepared in 1985, informing the public on features in the NLG 50/Sunflower. This first concept was tested among the employees of DNB and the suggestions for improvement were taken on board for the leaflet about the 250 gulden.

The introduction of the slogan "Feel Look Tilt" is a highlight in the policy to inform the public. This motto was developed to accompany the introduction of the euro in 2002 (subsection 3.5.2).
As central banks tend to introduce new public features all the time, they encounter perception and communication problems. Many new features are tilt features, often not univocal in their perception, for example hindered by the phenomenon of change blindness (subsection 5.4.5). Furthermore, when it comes to new public features, people tend to move from a wait-and-see attitude towards an apathetic attitude (section 5.6).

CLASSIFICATION OF COUNTERFEIT PRODUCERS		
Counterfeit producers	**Typical number of pieces made**	**Typical**
1. Primitive	1 - 2	Handmade reproductions at home. Reproductions made with a push-the-button colour copy (Canon CLC 1 since 1987). Desk top publishing, off-the-shelf equipment at home (> 1990).
2. Opportunist	5 - 10	Using home office equipment like PC, scanner, printer, editing software and other desk top publishing equipment.
3. Petty criminal	10 - 100	Using home office equipment plus specialty materials and processes.
4. Professional criminal	100 - 10,000	Using special equipment, special materials and organised crime. E.g. offset reproductions.
5. State-sponsored	> 10,000	Access to banknote production machines; state sponsored produced with the intention to destabilize hostile economies. Examples: 1775-1783 counterfeiting US currency by British Government (1775-1783). Operation Bernhard (1944). Super Dollar since 1989.

Figure 3.26
Five different groups of producers of counterfeited banknotes (National Research Council, 2007).

CLASSIFICATION OF COUNTERFEIT LEVELS		
Counterfeit level	**Parts per million (ppm)**	**Examples**
1	0 - 10	Japan, Norway, Sweden
2	10 - 50	Australia (2016), Hungary
3	50 - 100	Euro-area* , United States (excluding 1 USD)
4	100 - 200	Brazil
5	200 - 500	Canada (in 2004), Great Britain
6	500 - 1000	Canada (in 1973)
7	> 1,000	Somalia, up to 98 % are fake (since 1991). Coins of GBP 1 in 2014 reached 36,000 ppm.

*) Since 2011 most of the time below 50 ppm.

Figure 3.27
Seven levels of the number of counterfeits in parts per million (ppm). Usually calculated by the number of counterfeits taken out of circulation within one year, divided by the number of banknotes in circulation (De Heij, 2010a).

3.4.1 Counterfeiters

A counterfeiter does not have the same 'profession' as a forger. Definitions of a counterfeiter and a forger are arbitrary. It is commonly accepted that a counterfeiter makes an illegal *reproduction* of a banknote, while a forger makes an illegal *change of information* on a genuine banknote (Schell, 2007). With this definition in mind, an illegally reproduced banknote is a *counterfeit*, while altering the denomination of a genuine banknote is a *falsification*. In other languages, for example in Swedish, the counterfeiter was a person who changed the value of the note ("förfalskare"), while the person who makes a reproduction is the forger ("eftergjör/efteapar").
In the past, banknotes have been falsified, but modern banknotes are mainly reproductions and therefore forgers and counterfeiters are both referred to as counterfeiters, unwanted users of banknotes.
Counterfeiters apply different techniques to imitate a genuine banknote, classified either by *simulation* or *emulation*. Examples of simulation are a drawing or a colour copy and nothing, or almost nothing, is real of such simulated banknotes. Counterfeits created by emulation may include imitated authenticity features coming close to the original. A specific group are *composed notes*, which are fabricated by using parts of genuine banknotes as well as parts of reproductions of banknotes.

Five categories of counterfeit producers are distinguished in figure 3.26. Making single pieces at home are representatives of the first category, the *primitive* counterfeiters. The second category are the *opportunists* which produce typically 5 to 10 pieces. The *petty criminals* produce 10 to 100 (category 3) and *professional criminals* produce according to this classification 100 to 10,000 pieces (category 4). The highest volumes are *state-sponsored counterfeited banknotes* (category 5) produced by professional banknote printers.The first example within category 5 is thought to be Duke Galeazzo Sforza of Milan, demoralising in 1470 his opponent in Venice by flooding mimicked banknotes (Walz, 2012). Almost 300 years later, Frederick the Great (1712-1786) brought counterfeited banknotes into Poland during the Seven Years War (1756-1763). One more example is the American War of Independence (1776-1783). Both contending parties had their own banknotes, the "continentals" issued by Congress and the "bills of credit" issued by the States. First Congress mimicked the bills of credit in 1776 and the British reacted in 1777 with mass production of continentals, produced by an official British banknote printer. At the end of the war, hyperinflation made the continentals worthless. Several other examples of 'political counterfeits' followed, like in France (1793) and Russia (1806). In 1944, the Germans forced prisoners to counterfeit British banknotes, a story known as "Operation Bernhard" (subsection 1.2.2). A more recent example of state sponsored counterfeits is the "Super Dollar", first discovered in 1989 (National Research Council, 2007).

The previous introduced counterfeiters by their production volumes (figure 3.26). More relevant are the 'counterfeits per one million genuine banknotes in circulation' or *ppm*, an abbreviation for *pieces per million* or *parts per million* (Fürbach, 2017). Central banks usually opt for reporting the counterfeits in ppm/year. However, a country may have a counterfeit rate of 60 ppm and in a previous year 15 ppm. To solve this problem, the *monthly rolling average number of counterfeits per million notes in circulation* should be reported, in short *mranc/mnc* (De Heij, 2007). The mranc/mnc could be provided for each denomination or for all denomination together.

A remaining question is, how are the counterfeits registered, is it the number of counterfeits *passed*, *seized*, or both? Usually, the number of 'seized' counterfeits is kept out of the registration, as these counterfeits are removed before they reach circulation, as the result of police seizure of suspect premises. Counterfeits passed are the ones that reached circulation and were handed over to the central bank by the public, retailers, banks, cash transfer agencies and others. About 90 % of the counterfeits are detected at sorting systems and about 10 % by retailers, so is the experience of DNB. Lower denominations are usually mimicked in smaller quantities as high ATM-denominations (subsection 6.4.6).

People may accept a counterfeit without being aware that it is a mimicked note and return it back into circulation. People may also be aware of its mimicked status and still try to spend it, like a Black Pete. However, most counterfeiters seem to offer their bogus notes to retailers.
Figure 3.27 provides seven levels of the number of counterfeits in circulation and includes an example for each level. An average counterfeit level up to 50 ppm or 0.005 % is acceptable for most central banks, often based on an historical track record (De Heij, 2010a).

The user of a banknote is more interested in the *probability* to receive a bogus banknote than in ppm's. Central banks may provide figures on the probability to receive a fake banknote, although it is often not clarified how this calculation has been made. In Australia, most people will never see a counterfeit (Reserve Bank of Australia, 2014), which is logical as their ppm remains below 20. In the Netherlands, the probability to receive an imitated banknote is low, about 0.002 %, based on 40,000 counterfeits per year within an issuance of 2.000 million notes per year (De Nederlandsche Bank, 2013). According to the Bundesbank, to receive one counterfeit, a German person should live for 833 years (Handelsblatt, 2015).
A special situation exists in Somalia, where the probability to receive a counterfeited banknote is close to 100 % (Pilling, 2017). In the 1990s, the central bank lost control over the banknote circulation. Instead of Somali shillings, people opt for US dollar banknotes, which may also be a counterfeit. People in the rural areas are less well-off and must use counterfeited banknotes as if they are genuine. An alternative is offered by electronic payment channels. In the case of coins, there is the recent example of the British one pound coin. Based on a survey in 2014 it is reported that some 3 % of these coins had been faked or 36,000 counterfeits per million coins in circulation (The Royal Mint, 2017).

The provided probabilities are provided for private persons, receiving on average one or two banknotes a day, while retailers receive on average around 120 banknotes a day (subsection 1.3.1). Therefore, the probability that a retailer will receive a counterfeit is much larger. Indeed, counterfeiters target retailers, as reported by studies done in the USA (Morris et al., 2009) and the Netherlands (Van den Kommer et al., 2012). Subjects seem to be aware of the locations where counterfeits may be offered (Visser and Dijkers, 2013), typically being market places, restaurants, cafés and bars, fairs and retail stores.

An additional criterion to set a counterfeit level is offered by the *Simple Method* (De Heij, 2010a). The Simple Method contributes a score of 0, 1 or 2 points to the quality of the feature reproduced, respectively indicating that the feature is not imitated, obviously imitated or is a deceptive imitation. The first euro banknotes issued in 2002 have 6 public authenticity features, bringing the maximum counterfeit quality score on 12 points (= 6 x 2). When a counterfeit of a specific banknote model reaches the maximum of 12 points, the banknote should be replaced. Since 2008, DNB applies the Simple Method. The average score over the period 2008-2015 turns out to be 5.9 points (on a scale of 0 to 12 points), counterfeiters seem to settle for 50 %, as will be elaborated on in subsection 6.4.7.

Counterfeiters undermine the collective use of banknotes. Therefore, societies have penalties for counterfeiters, which used to be severe. In England counterfeiters were punished by hanging in the period 1697-1832 (Keyworth, 2013; Schell, 2007). To date, the punishment of counterfeiters is less severe.

Usually there are four aspects distinguished in a verdict, the quality of the reproduced banknotes (1), the volumes produced (2), the distribution network (3) and the volumes brought in circulation (4). All four are criminal offences. The maximum sentence in the Netherlands is nine years for producing and distributing counterfeited banknotes (Wetboek van Strafrecht, 2014). When people have brought counterfeits into circulation, they can be sentenced with a maximum of four years. A person trying to bring reproduced banknotes in circulation receives the same punishment, and includes the situation when a person tries to pay with an earlier accepted mimicked banknote.

A related subject is the social need for the imaging of money. Therefore, central banks allow the reproduction of banknotes, as long as the reproduction is obviously different from the original. Central banks have outlined reproduction rules for such an authorised reproduction of a banknote (e.g. European Central Bank, 2013a).

3.4.2 Three major counterfeit threats

Counterfeiters have been introduced (subsection 3.4.1) and this subsection continues with a limited review of the type of counterfeits the counterfeiters produced.
The first counterfeits were found immediately after the first banknotes were issued, so in the 17th century. Early imitations of banknotes were simulations, prepared by hand. In 1836, a completely hand drawn banknote was discovered in the Netherlands (Bolten, 1999). These first counterfeits were, because of their limited volumes, no major threat to the existence of banknotes.
Disruptive innovations in the graphic reproduction industry caused three major *counterfeit threats,* making it possible for counterfeiters to reproduce banknotes in large quantities (figure 3.28). First, there was the application of photography and lithography (around 1850), followed by the arrival of offset printing (around 1920). The innovations of digital printing are the third major threat (around 1985). Since the mid-1980s individuals may copy a banknote or may produce prints at home using desktop computer devices.
In the 1990s, the first digital images could be made by digital scanners. These images could - and stil can - be downloaded to a home computer and can be uploaded to the internet. In the early 2000s, digital cameras could make a digital image, which made it easier to upload images. By the year 2007, the first smartphones included a camera and by 2010 almost all smartphones did, bringing new opportunities of scanning banknotes.
These developments in the information technology made it possible that nowadays, a digital image of a banknote is freely available to anyone.

To date, central banks don't face a counterfeit threat, so is the opinion of the author, but a *usage threat*. In its essence, this usage threat is also a technical threat, although not triggered by developments in the graphic reproduction industry, but by developments in electronic payments. New payment instruments offer the public better services, the reason why people tend to turn their back towards cash, as will be elaborated on in subsection 8.2.1.

MAJOR THREATS TO THE USE OF BANKNOTES		
Time	**Threat**	
1. Around 1850	Counterfeit threat	Photolithography
2. Around 1920		Offset
3. Around 1985		Digital printing
4. Around 2015	Usage threat	Banknote users opt for digital payments

Figure 3.28
Four major threats to the use of banknotes.

3.4.3 Development of authenticity features

A comprehensive review of the development of authenticity features is not available, but parts of their history have been unveiled (Kranister, 1989; Keyworth, 2001; Schell, 2007; De Heij, 2010a; McCabe, 2016; De Heij, 2017). This subsection presents a review of the increase of the number of authenticity features, rather than their technical properties.

The first Western banknotes were issued in 1661 by Stockholms Banco and were mainly used by merchants (subsection 1.3.3). Other banknotes received a similar 'authenticity package' of five features, being a watermark (1), seals (2), relief border (3), numbers (4) and signatures (5). A similar set of features protected the first Dutch banknotes, issued in 1814, except for the seal (De Heij and Koeze, 1986). These features were based on different techniques, respectively paper making (watermark), paper embossing (seals), letterpress (relief border) and handwriting for the numbering as well as for the signatures.
There is no unequivocal definition of an authenticity feature; therefore, it is a separate topic how the number of authenticity features should be counted. For example, three different fluorescent fibres are added to banknote paper of the first series of euro banknotes, and when viewed under UV-light, visible as red, blue and green fibres. As the fibres are present on the front and on the reverse, one may count the fibres as six features, while others may consider fluorescent fibres as just one feature.

As early as the 17th century, central banks searched for entirely new authenticity features for their banknotes. In 1694, this search resulted in marbled paper introduced for the British pound notes (Keyworth, 2001). Different fibres, visible in daylight, were for the first added time in 1806 to the banknote paper of Wiener-Stadt-Banco (Kranister, 1989). In the 1960s, these fibres were made more secure, as they were invisible in daylight and visible under UV-light.
Since the 1970s, some rivalry is observed between central banks (Schell, 2007). New designs and new features receive attention from others, the reason to try being the first. The last decades, especially foil and colour changing features received attention (De Heij, 2017). This rivalry is all too often not for the benefit of the user; technically advanced features are selected above user-friendly ones, as is the author's opnion.

Adding features to banknotes increased their number, a case of "feature creep", the tendency for things to become incrementally more complex until they no longer perform their original functions very well (Heath and Heath, 2007). Later, Norman (2013) phrased this tendency as "creeping featurism". In 1995, the Swiss banknotes set a record, when 30 authenticity features were incorporated (Swiss National Bank, 1995). The public features were clarified in the leaflets, but a complete list with all 30 features was not provided. The Swiss record was broken by the euro banknotes in 2002, as these incorporated 33 features (McCallum, 2009), while others speculated on 26 (Bender, 2004) or even 37 features (Albers, 2001). Adopting the euro banknotes, central banks kept using their sorting equipment, one of the reasons of the high number of features in the euro.
Obviously, the banknote printing industry is content with high number of features. For example, KBA-Giori, a manufacturer of banknote printing machines, demonstrated in 2004 that more than 50 features can be incorporated in their promotional banknote dedicated to Jules Verne (1828-1905) (Schell, 2007).

As noted in the introduction of this section, central banks did not inform the public on authenticity features up to 1976 (section 3.4). To authenticate a banknote, if at all, the public had to use the same features as bank cashiers, except that cashiers have a magnifier and a ruler within reach.
Bringing authenticity features to the public domain created two new terms: *covert* and *overt features* (De Heij, 2010a). Covert banknote features are not visible to the human eye and should remain unpublished as they are intended to be used by detectors or by other specific devices, like a microscope or spectrophotometer. Overt authenticity features are features visible for the human eye, authenticity features for public use.

Koeze (1982b) identified *security features for the public*, defining the users of authenticity features in four categories: public (1), banknote acceptors (2), commercial banks (3) and central bank (4). Since then, several contributions have been made to the classification of authenticity features by the way they are checked. In 1998, Wieland introduced the term of *defence lines*. Checking a document like a passport or a banknote without any equipment is a first-line inspection and when simple tools are applied is a second-line inspection. Finally, a third-line inspection is carried out by forensic specialists using sophisticated means. This approach was adopted for the introduction of the euro in 2002, renaming the defence lines in respectively *Level 1*, *Level 2* and *Level 3 (*e.g. Heinonen, 2007).

Later, Level 2 was divided in three *sublevels*, respectively covering handheld devices (*Level 2a*), automatic devices (*Level 2b*) and banknote recycling machines (*Level 2c*). Still, these levels do not cover all situations how features are operated, triggering the proposal to add *Level 0*, *Level 4* and *Level 5*, respectively aiming for *trigger features* (Level 0), features part of Counterfeit Deterrence Systems (Level 4) and forensic features (Level 5) (De Heij, 2010a).

The present situation is presented in figure 3.29. The first column lists how the features are checked, for example by a hand-held device like a magnifier or a UV-lamp. The second column provides a name for each category, like *Level 2a*, a technology-driven naming, as it doesn't unveil the user. The third column provides a use-centered name for the features to be checked. Public features were introduced in the 1980s, to involve the public as a first line of defence against the spread of counterfeited banknotes. However, the world has changed and to date the attitude of the Dutch towards an authenticity self-check is on the decline, as indicated by measurements reported in subsection 6.4.6. And they are right. Banknotes withdrawn from an ATM are checked on genuineness and fitness before they are re-issued, a result of the ECB's policy to on the recirculation of euro banknotes, first the 'Recycling Framework' was introduced in 2005, followed by the ECB's decision in 2010 (European Central Bank, 2010a). Most of these genuine ATM-notes are brought to the shops, where people receive their change in lower denominations and coins. Lower denominations are usually mimicked in smaller quantities as high ATM-denominations (subsection 6.4.4). People witness retailers passing banknotes through devices, encouraging their trust. Confidence is further fostered by fully automated systems for cash payments at the checkout counters, providing people's change. Such automated services for making a cash payment are widely used in Japan and are also becoming available in the Netherlands.

CLASSIFICATION OF AUTHENTICITY FEATURES		
The features are checked by	**Name giving Technology-driven**	**Name giving Use-centered**
Human senses - subconscious	Level 0	Public trigger features
Human senses - conscious	Level 1	Public features
Hand-held devices	Level 2a	Retail features - human operated
Automatic devices	Level 2b	Retail features - automatic device
Banknote recycling machines	Level 2c	Commercial cash centre features
Sorting machines of central bank	Level 3	Central bank features
Counterfeit Deterrence System	Level 4	Features to prevent home-made reproductions
Expertise in laboratories	Level 5	Forensic features

Figure 3.29
Classification of authenticity features. Naming of authenticity features of banknotes within a technology-driven design policy and within a use-centered design policy. The levels as used by central banks and the banknote printing industry are marked by the thicker line.

An authenticity self-check seems to be only required on special occasions, like in case of special festivities, like a fair, or a purchase from a private person on the internet (subsection 3.4.1). In such cases people may use an app on their smart phone to check a suspect banknote.
Although people do not want to check banknotes for authenticity the notes should exude confidence. And they do; studies in Canada and the Netherlands show that people have a high, stable and increasing trust in banknotes (subsection 6.8.1).

3.4.4 Search tasks

People encounter problems when they want to do an authenticity self-check. First, they do not know where the public features are. Subjects found half (3.9 features) of the average of 7.7 features which are promoted in information tools of central banks (Masuda et al., 2015). An example is the explanation of the feel feature of euro banknotes: "Feel the banknote. It should be crisp and firm. Run your finger across the front of the banknote and you will feel that the ink is thicker in some parts" (European Central Bank, 2007b). Crisp and firm are multi interpretable terms and it is also not clear in which area people should move their finger to and fro.
Shortcomings in finding a feature is an argument to enhance the design of authenticity features by highlighting such features. One may opt for an *intuitive navigation route*, as demonstrated by a design of an older French banknote, shown in figure 3.30.
Information leaflets often accompany the introduction of a new banknote (subsection 3.4.3). Such leaflets explain where the public features can be found and how they should be used. To indicate the location of a feature, a *signifier* is used, like a line, arrow, number or letter. Since banknotes are printed matter, signifiers could be printed directly on the banknote by means of *search features,* features which support the finding of public authenticity features. An alternative term is *wayfinding features,* a term introduced by Arthur and Passini (1992). Furthermore, people must navigate from one feature to another, following a *navigation route*.

Intuitive navigation route

Figure 3.30
An example of an intuitive navigation route, a banknote of 100 franc, issued in 1941. The suggestion is given that the woman looks in a mirror, which represents a watermark, the image of her face.

SIGNIFIERS WITHIN A BANKNOTE				
Search feature	**Serving user need**	**User action**	**Design principle**	**Example**
1. Coordinates	What to look for?	1. Orientation	A map, letters and figures, like A3	Swiss banknotes, 1995
	Where is it?	2. Navigation		
2. Marks	Is this the feature?	3. Identification	A mark, like a letter, arrow or icon	Test notes DNB/ECB, 2005; A-R-U-B-A design, 2007
3. Instruction symbols	What to do?	4. Instruction	Feel, look-at, look-through, tilt	

Figure 3.31
Overview of different signifiers within a banknote.

Figure 3.31 presents an overview of the signifiers applied to banknotes, listing three different types of search features: coordinates (1), marks (2) and instruction symbols (3), which will be explained further on. Search features support specific user needs like 'what to look for?' and 'where is it?' These user needs are followed up by a *user action*, like orientation and navigation. The design of the search feature may assist a user action, for example, by the coordinates of a map, like A3. Once the feature is found, the user wants to be reassured, is this the feature? Confirmation can be provided by a mark, like an icon. Finally, an instruction symbol may inform on how the feature should be checked, by feel, look-at, look-through or tilt.

1. Coordinates

The first banknote incorporating signifiers was issued in Switzerland in 1995 (figure 3.32a), small letter coordinates were printed along the banknote's edge, providing also a navigation route (figure 3.32b). All features were designed as variants of the numerals. Although clear in set-up, the result was not unambiguous. First, the height of the letters is about 2 mm, too small to be obvious (figure 3.32c). Second, the letters A until H suggests eight features, while the communication slogan is "5 easy to check" (Swiss National Bank, 1995). Furthermore, other public features had to be checked, like a watermark and see-through register, which did not receive a coordinate and were located at random positions.
In 2016, the first model of a new series of Swiss banknotes was issued. The coordinates were no longer applied, probably because the public did not use them.

2. Marks

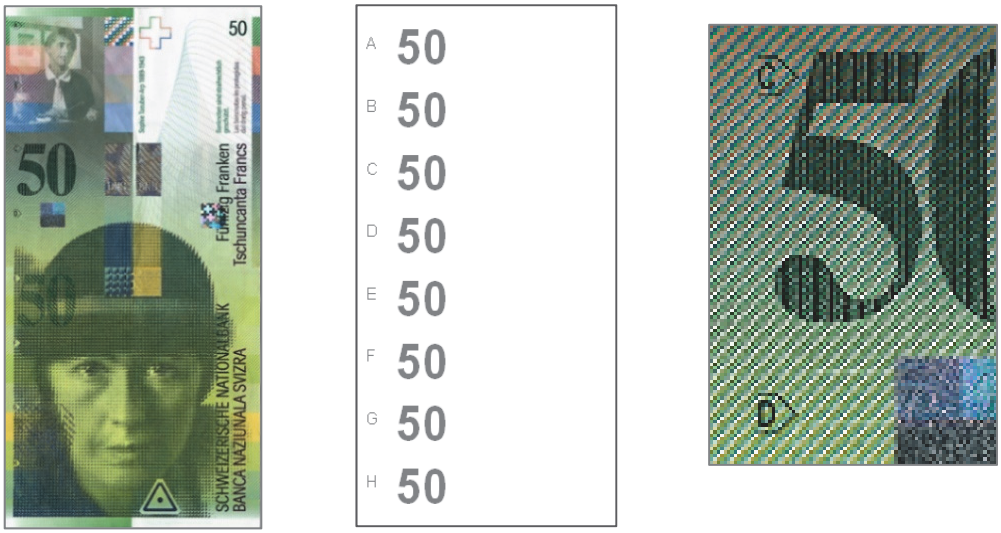
The Swiss search features could be made more appealing, by a more playful design. Instead of coordinates, randomly spread letters can be used. When these letters have a meaning, the navigation route becomes a *retrieval path*, like the well-known 'Turn left at the red mail box' (Reif, 2008). An example is provided in figure 3.33a. People will understand that these letters form the word A-R-U-B-A and that an authenticity feature may be found near each letter. Tracing letters of a word addresses the playing man, the *homo ludens* (Huizinga, 1950). Using this principle other designs can be made as well, like a conceptual design for a new euro banknote using the letters E-U-R-O-P-A, E-U-R-O, or E-U-R, depending on the number of public features used (De Heij, 2012) Another example is 'search the fishes' (figure 3.33b). Such an approach also fulfils the communication recommendation of a short story (subsection 3.5.1). Obviously, such signifiers should attract the eye and should have a height of at least 3.5 mm, a result of a dedicated study to signifiers, as will be elaborated on in the next topic.

3. Instruction symbols

The previous two topics introduced two types of search features, coordinates (topic 1) and marks (topic 2). A third type of search features are instruction symbols, based on human handling like feeling, looking-at, looking-through or tilting, symbols which were in 2003 subject of research (De Heij, 2006a). Instruction symbols (figure 3.34) were designed by Paul Mijksenaar (born 1944) and subsequently tested for their comprehensibility (Boersema, 2006). The next step was a user validation with test banknotes. Two sets of identical test notes were prepared, one standard and one including instruction symbols as proposed (figure 3.34c). Both sets contained six public authenticity features, four were printed on the front and two on the reverse. Furthermore, two symbols were - on purpose - slightly hidden, to explore if people would find these symbols anyway. Each search feature includes a unique mark, in case the letters A until F, of which the feature marked with F was obvious. This assisted respondents to conclude that they have found all. The outcome of this study was that respondents found on average 1.8 feature on the reference notes, pieces without instruction symbols (De Heij, 2007). This score increased significantly to 4.7 on the notes with the instruction symbols, after respondents were told that near each public feature a symbol has been printed. Once people identified an instruction symbol, they understood what to do next, i.e. feel, look or tilt. The features on the back, E and F, were less used, in line with the finding that people do not pay much attention to the reverse of a banknote (subsection 6.4.1).

First search features on Swiss banknotes (1995)

CHF 50 (1995) | Navigation route | Detail symbols C and D

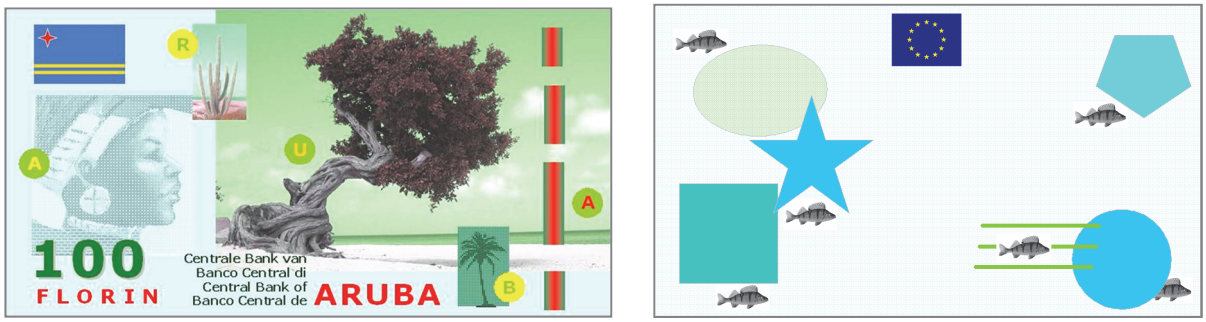


a) b) c)

Figure 3.32
First banknote with search features and a navigation route to find the public authenticity features, in case letter-coordinates A until H. This Swiss CHF 50/Sophie Taeuber was first issued on 3 October 1995. Designer: Jürgen Zintzmeyer.
a) Front of CHF 50/Sophie Taeuber.
b) The layout principle, i.e. the denomination numeral, in this case 50, is repeated 8 items. Each numeral received a small letter-coordinate, A-H. Image: De Heij.
c) Detail of the letter-coordinates C and D.

Navigation routes based on retrieval paths

Conceptual note A-R-U-B-A (2007) | Conceptual note fish (2010)



a) b)

Figure 3.33
Conceptual banknote designs illustrating a navigation route based on a retrieval path.
a) Design for a 100 Florin banknote for the Central Bank of Aruba. Five public security features may be found by following the letters A-R-U-B-A. Design by De Heij (2007), published with the permission of the Central Bank of Aruba.
b) Theme 'Search all fishes'. A small fish icon can be found close to each public security feature. The features could be designed from using themes like water, water plants, boat or fisher man. Another denomination could have 'follow the bee' or 'follow the helicopter' for a theme (De Heij, 2010a).

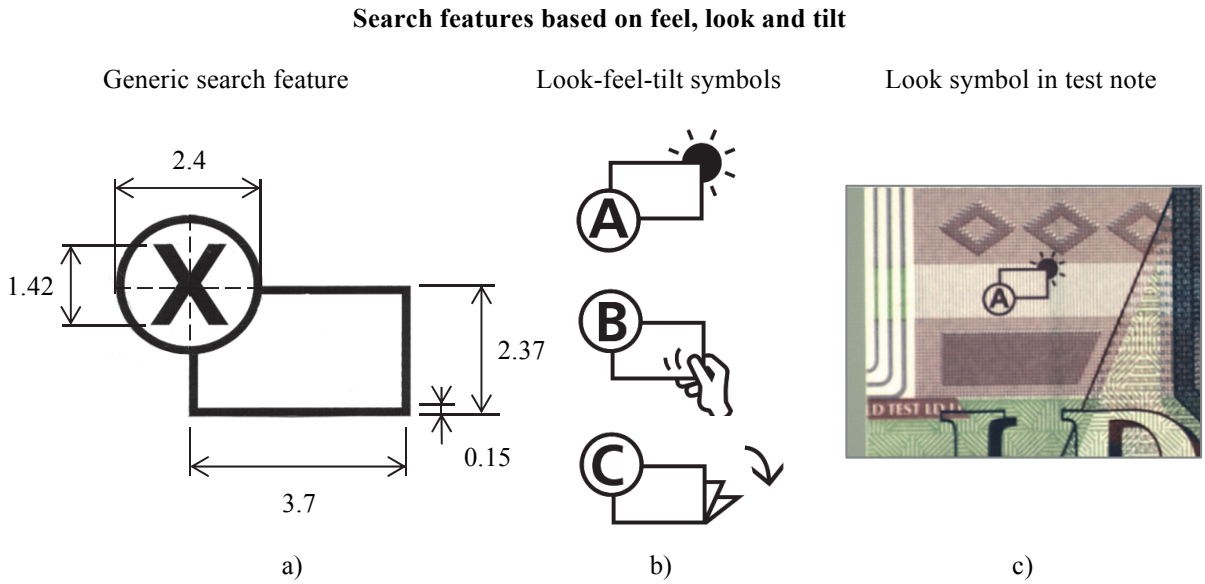


Figure 3.34
The design of search features based on feel, look and tilt.
a) Basic construction reference and dimensions in mm of a search feature.
The letter should be visually centralised into the circle, letter type Frutiger 65 Bold, font size 5.5 pts (capital height: 1.35 mm). Design: Paul Mijksenaar.
b) Examples of search features look-through (A), feel (B) and tilt (C).
c) Example of search feature look with the letter A, near the security thread of a dummy note (2005).

3.4.5 User groups and authenticity features

Central banks tend to add more-and-more new authenticity features to their banknotes. How to handle this from a methodological point of view? Basically, there are two approaches. The first limits the total number of authenticity features (topic 1) and the second limits the number of authenticity features per user group (topic 2).

1. Limit the total number of authenticity features

By limiting the total number, features must be dropped when new ones come in. This principle has been applied for the first time during the design process of the NLG 100/Little owl in 1990. In this case, the limit was set at 20, being the number of authenticity features used in the previous banknote design (De Heij, 2000).

2. Limit the total number of authenticity features per user group

User groups have been introduced in section 2.6. At the time of the gulden banknotes it was DNB's policy to include three authenticity features for automatic sorting of banknotes at the central bank. About one billion banknotes (10^9) were sorted on a yearly basis (Van Gelder and De Heij, 1992) and a slip rate for counterfeit banknotes was accepted of one counterfeit per billion. Recalculating, the probability that a counterfeit may pass one detector came out on 1 in 1,000. The second assumption is that authenticity features are statistically independent from each other, as they represent different security technologies, respectively paper (1), print (2) and numbering (3). Subsequently, the probability that all three features becoming reproduced was calculated to be (10^{-3}) x (10^{-3}) x (10^{-3}) = 10^{-9}, or 1 in 1,000,000,000 (De Heij, 2010a). At the time of the former gulden banknotes, this was considered a low probability and it was the opinion of DNB that the perfect reproduction of gulden banknotes was close to impossible.

When this same argumentation is applied to multiple user groups, the total amount of features (N) can be set. In case of six user groups, and three authenticity features per user group, the banknote would carry 18 authenticity features (N = 6 x 3).
A *generic authenticity matrix* is presented in figure 3.35 (De Heij, 2010a), prescribing three authenticity features for each user group, but does not indicate what these features are.

Adopting the principle of three authenticity features per user group, the next question to be answered relates to what the requirements should be. The features for the public are reported first, followed by features for retailers.
The public cannot memorise more than four text elements, four picture elements or four authenticity features (De Heij, 2002a; 2006a). Concluding from these studies, the maximum number of public authenticity features is four. On average, people recall two to three authenticity features, as will be reported on in subsection 6.4.2. Therefore, three public features are enough, matching the limit of three features per user group. A fourth public feature could included in the design, receiving the status of a *sleeping feature*, to be awakened when one of the other three are no longer effective (De Heij, 2007).

Before starting the feature selection, first the preferred human actions should be determined, indicated by the left side of figure 3.36. Public features are based on human actions, like feel, look-at, look-through and tilt. A smart phone is also added.
The centre of figure 3.36 presents the situation of the first series of euro banknotes, which included six public authenticity features. One of these features, a tilt feature, is on the back and the other five are on the front. There is no look-at feature and there is no feature for a smart phone.
An alternative series is presented on the right side of figure 3.36. The three required features are first defined by their human action, respectively feel, look-at and tilt. The feel feature is not visible and is positioned on the reverse, so that the index finger, which is the most sensitive, will interact with a tactile structure (subsection 5.2.2).

Once the human actions are defined, the phase of stock picking of authenticity features may start, based on the user needs (figure 3.37). This overview is based on the user needs introduced in "Banknote design for retailers and public" (De Heij, 2010a). Checking a banknote at one glance and similar features in all denominations are the two main drivers.
Feature selection should not only be based on user needs, but also be grounded on technical criteria, which should be balanced over different physical and chemical phenomena identified in the "System-approach" (De Heij, 2010a), a topic outside the scope of this thesis.
In a similar exercise as for the public, the selection of authenticity features for retailers is proposed (figure 3.38). The first series of euro banknotes included eight authenticity features for retailers, divided over the front and the back, while an alternative series incorporates three such features. Following the use-centered concept of a public front and a retail back (subsection 3.3.1), all these features are positioned on the back. Two features are targeted for automatic detection, in line with the trend of an increased use of automated inspection devices, as will be elaborated on in subsection 6.4.6; one feature is targeted for human assisted detection.
The present approach of central banks is unlike the just described policy. Central banks tend to promote features for retailers, which do not match with the retailers' user requirements. As a result, retailers tend to use their own, non-official features (Sabohi, 2012). Examples are rubbing the note on white paper, folding the note to see if toner comes off, tearing the banknote along its thread and marking a banknote with a specific pen, leaving a yellowish trace in case of a suspected banknote. This British study also reports that retailers only check one in every five notes.
A specific case are banknotes circulating in closed communities, like cruise ships. After checking employees may put a small stamp on a banknote, as a mark that it has already been verified.

GENERIC MATRIX OF AUTHENTICITY FEATURES		
User group	**Type of authenticity feature**	**Number**
1. Public	a) Trigger (at one glance)	3
	b) Public features, feel-look-tilt	
2. Retailers	a) Automatic device in shop	3
	b) Human-operated, visible	
3. People using banknote machines	a) Banknote acceptors	3
	b) Detector third-party sorting	
4. Employees of central banks operating banknote sorting machines	Banknote sorting machine	3
5. People reproducing banknotes at home (Counterfeit Deterrence Systems)	a) Colour copy machines	3
	b) Scanners, all-in-one devices	
6. Forensic people	Only detectable with professional tools.	3
Total (N)		18

Figure 3.35
Generic matrix of the distribution of authenticity features over a banknote, listing the different user groups and their type of features.

HUMAN ACTION - FEATURE MATRIX				
Action by user	**Authenticity features for the public**			
	a) Euro series 2002		b) Alternative series	
	Front	Back	Front	Back
Feel	1	-	-	1
Look-at	-	-	1	-
Look-through	3	-	-	-
Tilt	1	1	-	-
Use smartphone	-	-	1	-

Figure 3.36
Human action-feature matrix for two series of banknotes.
a) Euro series 2002. Six public authenticity features are divided over feel, look-at, look-through and tilt. The features are also divided over the front (5) and back (1).
b) A proposal for an alternative series of banknotes, including three public features. On the front, a look-at feature and on the reverse a feel feature. The third feature is checked by a smartphone with a camera.

User needs **Authenticity features for the public**	
User need	**Description**
1. Check at one glance	With three features advised to be verified, a complete authentication at one glance. All features on the front.
2. Similar in all denominations	Authenticity features should be similar through a series. Cross references will assist the user looking for an authenticity feature.
3. Feature name	Without a name, people do not know what to look for (linguistic determinism).
4. Easy to find	Keeping the banknote at a reading distance (0.3 m to 0.4 m), human eyes would typically focus on object sizes of about 30 mm x 15 mm. Read from left to right (and nor from top to bottom).
5. Understandable	Is it clear if the features should be: felt, tilted, looked-through or should be looked-at? Is it clear how this effect should be for real banknotes and for counterfeited banknotes?
6. Univocal	A clear yes-or-no decision, unequivocal discrimination between a real and a counterfeit banknote.
7. Equal perception	Perception of public features should be equivalent. When one feature attracts too much attention, people will tend to check just this feature; maximising one feature at the expense of others should be avoided.
8. Durable	The feature should work under different light conditions and temperatures, by the young and the elderly. A security feature which loses its characteristics by wear and tear will complicate an authenticity check. Security features should be hard-wearing.
9. Single user group	A feature should serve just one user group, in case the public (to prevent sub-optimization for one or more other user groups).
10. Time	Authenticity features for the public should be operated in 2 to 3 s.
11. Delicate	People do not want to offend others when they examine a just received banknote. Feel and look-at are preferred. Look-through and tilt actions can hardly be done discretely.
12. Striking	The desired authenticity feature should be striking and provide pleasure during checking (the playing man: homo ludens). Realistic images should be used as part of a story.
13. No nesting	The banknote itself is considered as one security product (nest level 0). Individual public features start at nest level 1 and should not include a second nest level. To force the counterfeiter to layer their work, higher nest levels may be included, but not for public use.
14. No repetition	Avoid repetition of design elements like numerals or currency symbols. People will be discouraged; should they all be checked? Should they all be the same? Should I start at the top or just pick one?

Figure 3.37
User needs on verify authenticity features for the public (De Heij, 2010a and the references therein; De Heij, 2016d).

TOOL - FEATURE MATRIX				
Tools used by retailer	**Authenticity features for retailers**			
	a) Euro series 2002		b) Alternative series	
	Front	Back	Front	Back
Automatic device				
1. Feature by central bank	> 1	> 1	-	1
2. Feature left to market	> 1	> 1	-	1
Human operated				
3. Feature by central bank	2	2	-	1

Figure 3.38
Tool-feature matrix for authenticity features for retailers for two series of banknotes.
a) Euro series 2002. At least eight features for retailers are divided over the front and the back. Feature by central bank, automatic device (e.g. magnetic thread). Feature left to market by automatic device (e.g. IR). Feature by central bank human operated (e.g. UV and micro-text).
b) Alternative series. Proposing two features for automatic devices and one dedicated human operated retail feature.

User needs **Authenticity features for retailers**	
Retailer needs	**Description**
1. Maximum 2 s	Ideally, retailers do not want to spend any more than (probably) 10 s checking each note (and rather not at all). Neither do they want to engage the public in a discussion or debate - so a combined feature and device are required, providing an independent and unequivocal validation within 2 s.
2. Do not want to make customer uncertain or offend customer	Retailers would rather not check banknotes. A customer may become uncertain and may think 'hopefully my banknote is all right'. A customer might also feel offended.
3. Automatic device preferred over human-assist	Retailers would like future banknotes to be ready for more secure automatic devices instead of human-assisted retail features.
4. No false alarms	Using a device, retailers would like to keep the false alarms close to zero (rather than a miss.)
5. Keep effect of human-assist features similar	Returning design elements should have a similar effect (e.g. under ultraviolet light or under an infrared viewer).
6. Backwards compatible	Authenticity devices should be usable for both the old and the new banknotes (backward compatibility of authenticity devices).
7. Return suspicious note to client	Retailers would prefer to return suspicious banknotes to the client and ask for another one or for having the payment settled through other means, for example by using a debit card.
8. Check just one side	Retailers would like to have all human-assisted features on one side of the note.
9. Independent of any source	The human-assisted feature is independent of any source of energy (no electricity, no batteries).
10. Do not like high denominations	Retailer would rather not accept high denominations (non-ATM denominations).
11. No magnifying glass features	Retailers do not use a magnifying glass (large shops or casinos with a back office might use a strong magnifier).

Figure 3.39
User needs on authenticity features for retailers (De Heij, 2010a).

One more example of a mismatch between features offered and the user is the introduction of a 'double UV check' for euro banknotes in 2013. The use of UV as a retail feature has already been questioned in the 2000s (Jonker et al., 2006), as the feature was well imitated on counterfeited banknotes and often looked more real (De Heij, 2010a). Instead of checking a banknote by one type of UV-light (365 nm), banknotes part of the Europa Series may be verified by two types of UV-light (254 nm and 365 nm). Checking a feature by two wavelengths is more secure, but to the retailer it is, most likely, too time consuming.
Figure 3.39 presents the collected user needs of retailers towards an authenticity check, a similar type of overview as prepared for the public. The time needed to perform an authenticity check will be the first user need of a retailer, so is the author's assumption. Two user needs conflict with each other, respectively making a customer uncertain and the return of a suspicious note to the client.

Summarising, the number of authenticity features in a banknote is the result of different features for different user groups. Per user group the number of features should be capped at three. In case of authenticity features for public use the human action should be determined first, preferable feel and look-at. Subsequently, a technique is selected to prevent counterfeiting. In case of retail features, first the tools/devices should be determined.

3.5 Receiving communication messages (UIF 4)

The last User Interface Function of a banknote is the reception of the communication message (UIF 4). According to Peters (1999), the mass communication function of money is underestimated: "Money, after all, is a kind of medium - and not only a medium of exchange, but a medium of representations as well". Heinonen (2009a) published "Lessons in Banknote Communication", emphasising the need of consistent communication of the public authenticity features of banknotes. Furthermore, the development of banknote communications should start at the design phase, rather than once the banknotes have already been designed.

The semantics of banknotes is provided by the communication messages, appearing for the first time in the Prosperity period (subsection 1.3.3), like 'ships under sail'. Portraits dominated the next three design periods of the Classification of Banknote Design Periods, the periods of Small Portraits, Great Men, and Great Men and Women. At first these portraits supported confidence (UXF 3) and later portraits underlined also the national identity (UXF 1). First examples of portraits that emphasise the identity appear in the 1870s, for example in Spain.
Apparently, modern banknote design falls short on attracting public attention, as central banks tend to increase their promotion activities to gain public awareness. Since 2003, upgraded designs of US dollar banknotes are promoted by game shows on television and celebrities from the entertainment industry (Atkinson, 2003). Spectacular was the unveiling in 2013 of a new Canadian banknote in a spacecraft; the astronaut had taken the new design with him months in advance (Suchack, 2013). The central object in the promotional campaign of the Europa Series is an ancient vase with an image of Europa (European Central Bank, 2015b). The introduction of the euro 50 in 2017 in the Netherlands was accompanied by a special coat design, using a synthetic, transparent plastic. Using the same material, over 200 pockets were created, each showing the new banknote model. Another promotional activity supported by DNB was a security truck displaying the euro 50, surrounded by many flowers, as part of a major Flower Corso.

People have selective attention and will favour information which is perceived as important to them, a general principle, also applicable to the communication messages of banknotes. Therefore, the development of such messages should start with gaining knowledge about the receiver, what would people like to see. To arrive at such a *receiver-oriented communication* the main drivers of public interest should be identified first, a topic which has attracted little scholarly attention (Lauer, 2008). All too often the sender is dominant and the receiver must adjust (Chandler and Munday, 2011). *Sender-oriented communication* is quite common for bureaucratic organisations and seems to be also true for central banks when it comes to the communication messages within banknote design.

Usually, so is the observation of the author, central banks start a banknote design project without a complete *overall communication plan*. Such a plan will avoid the convulsive search for communication messages after finishing the designs. Such a plan will also prevent a myriad of messages, as identified within the two-circulating series of euro banknotes, as will be elaborated on in subsection 3.5.1. Indeed, the communication aspects of banknotes should become part of the banknote design in an early stage (IBDA Working Group, 2014).
As banknotes are used by different user groups, the *communication policy* of a new banknote should address all, as indicated in figure 3.40. This figure also includes stakeholders of automatic devices (BEMs), next to the public and the retailers, as these stakeholders are key to a smooth introduction of a new banknote model (subsection 1.3.1).
Communication messages of banknotes are split in information on authenticity features (UIF 1) and in messages part of the banknote design, like communication messages of the banknote (UIF 4), the banknote theme (UXF 1) and the choice of the main image (UXF 4). The public should be informed on the public features and on the communication messages, theme and main image. Retailers and suppliers of devices will also hear about these messages, as they are also part of the public. However, in their role as retailer or supplier, these messages are not relevant. Retailers need to be informed on all three types of authenticity features, while the suppliers of devices must only be informed on human operated and automatic devices.

3.5.1 Communication plan

The banknote model "Snipe" was introduced in 1981. Its short, funny name was one of its success factors, illustrating the strength of *linguistic determinism*, as will be elaborated on in subsection 5.4.5. This success came unexpected, as there was no policy on name giving, a topic receiving little attention within a banknote design project. Nicknames given to banknotes point in the same direction of uncomplicated name giving, like "green back" (subsection 3.2.3). One more example is "grant", a synonym of fifty dollar, derived from Ulysses S. Grant (1822-1885), the 18th President of the United States, whose portrait features this denomination. These examples indicate that name giving within a series of banknotes should be done by one or two words or syllabi.

An overall communication plan includes six stages and starts with name giving according to a breakdown structure as offered in figure 3.41. This figure includes an example of an imaginary banknote series as could have been issued in the second half of the 19th century. In retrospect, the corresponding identity description would be 'Hard working nation', which led to the theme 'Prosperity'. A name for the series is found by interpreting the theme of prosperity, leading to 'Industry and trade'. The next step is to identify a theme for each denomination, for example 'Factories' and 'Ships under sail'. Names for the individual notes are derived from the theme assigned, like 'Smoking chimneys' for the factory theme. Authenticity features for this denomination could have been 'Worker' and 'Steam engine'.
The six steps identified in figure 3.41 are introduced by following corresponding topics: identity description (topic 1), theme of the series (topic 2), name of the series (topic 3), theme of the banknotes (topic 4), a name for each denomination (topic 5) and names for the public authenticity features (topic 6).

1. Identity description

The start of a communication plan is an *identity description,* a short text of about half A4 telling what kind of experiences the new banknote design should evoke. The banknote's identity is part of the User Experience Functions (UXF 1) and will be introduced in more detail in section 4.2, examples of identity descriptions are provided in subsection 4.2.4.
As knowledge on the national identity is not an expertise of the central bank, the preparation of the identity description could be outsourced to a communication agency (De Heij, 2007; 2012). The main theme of the series and the name of the series could also be left to such professionals, just as the development of a motto.

COMMUNICATION POLICY						
User groups/ stakeholder	**Communication message(s) on**					
	Authenticity features			Messages part of the banknote design		
	UIF 1			UIF 4	UXF 1	UXF 4
	Public features	Human operated devices	Automatic devices	Messages	Theme	Main image
1. Public	x			x	x	x
2. Retailers	x	x	x			
3. Suppliers of devices		x	x			

Figure 3.40
Addressing different communication messages to different user groups and stakeholders.

Breakdown of an Overall Communication Plan for the Design of a Banknote

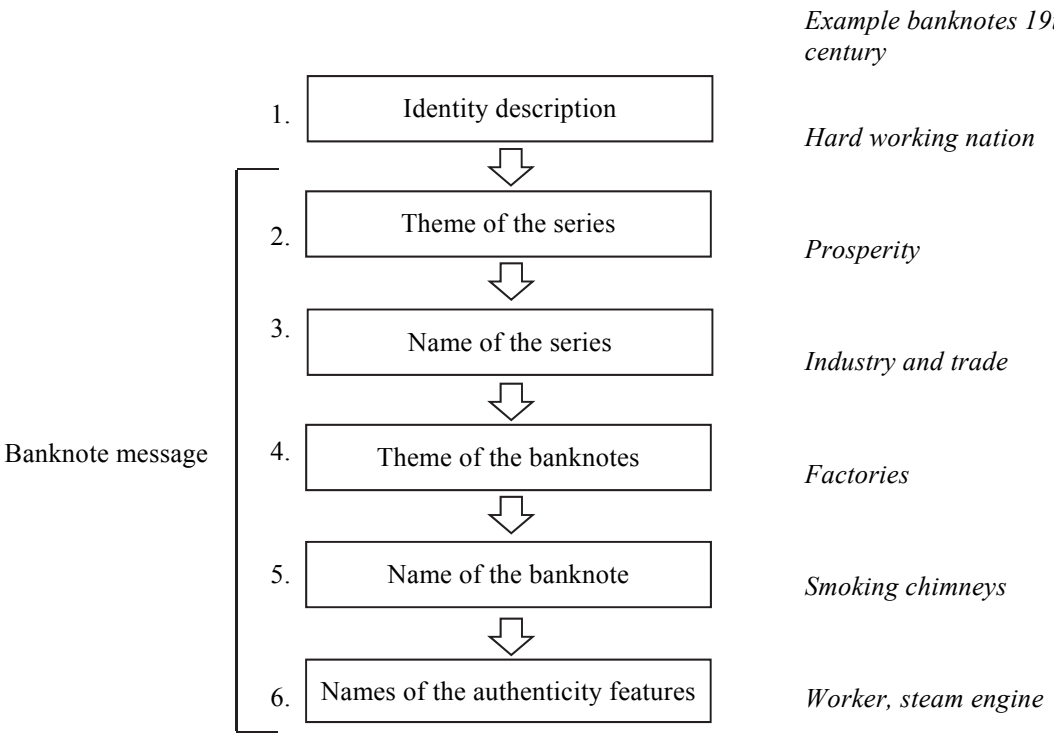


Figure 3.41
Breakdown structure of an overall communication plan for the design of a banknote, from identity description to names for authenticity features. The designer, communication advisor or the central bank provides the motto or theme and in three sequential steps the name of the series, individual banknotes and authenticity features are developed.

2. Theme and motto of the series

The step of an identity description is followed by the stage of the search for a theme and a motto. Themes on banknotes have been classified by the "Function Systems of Society" as proposed by Roth (2014). This Function Systems distinguishes the following ten categories: politics (1), economy (2), science (3), art (4), religion (5), legal system (6), health system (7), sport (8), education (9) and mass media (10). Subsequently, the study classifies the themes applied to the euro coins and banknotes. Subject of study were 162 variants of euro coins and 7 variants of euro banknotes. In total 422 symbols were counted of which 416 could be classified according to this Function Systems. The score was as follows: politics (24.6 %), economy (22.9 %), mass media (22.0 %), art (21.3 %) and legal system (9.2 %). The other categories were absent. According to Roth the most striking is the disappearance of the category 'science' on euro banknotes, which was well represented on the French and German currencies.
The study on the Function Systems reveals that there are at least ten theme-categories for a banknote design. What the Functions Systems does not show is how a theme can be attractively designed, which is perhaps even more important to attract the public's attention than the theme itself.

According to Stilitz, who has been introduced in subsection 3.2.4, the starting point for finding a suitable theme for a new series is a *little story*: "Design content should be strongly linked through a common story" (study reported in: De Heij, 2007). General rules for a little story are a clear starting point, followed by the middle part, the drama and should finish with a clear ending, the solution. The story should not be childish and should address emotions rather than rationalities. A storyline should not become a puzzle. An illustrative example is the sunflower and the bee on the NLG 50/Sunflower (figure 1.1b). Scratching with a finger nail on a set of parallel lines, the sound of a humming bee is heard. In case of the NLG 100/Little owl (figure 1.2c) the owl's prey, a mouse is displayed in the see-through register, where one part on the front should match with a complementary part on the reverse. Story telling may gain influence on future banknote designs, as flagged by the Swiss banknotes, first issued in 2016. Banknote designer Manuela Pfrunder (born 1979) introduced the *protagonist*, not a person, but a theme telling its story, like *time* (CHF 10), *light* (CHF 20) and *wind* (CHF 50) (Swiss National Bank, 2016a).

3. Name giving of the series

The name of a series is triggered by its theme (stage 3 in figure 3.41). Providing a name to a series of banknotes can be done in several ways, ranging from a neutral name to an appealing one. Identifying a series of banknotes with letters, such as A, B and C-series, are examples of neutral naming, a method applied by the Bank of England and several other central banks. Instead of a letter, series may also receive a number, like the 16th series of the bath currency issued in Thailand in 2012.
Another example is the second series of euro banknotes, called ES2, an abbreviation of Euro Series 2. Later this series received the name "Europa Series" after the design of its first denomination, the euro 5, was ready for issuance.
Applying a letter or a number to a series are expressions of a technology driven design policy. In a use-centered design, first an overall communication policy is established. The name of the series should be catchy, a short text of one or two words, like "Canadian Journey" (Canada, 2001), "Brighter Colours" (New Zealand, 2015) and "The Sea" (Norway, 2017).

4. Theme of the banknotes

The theme of a denomination within a series is triggered by the name of the series or motto. An example is the theme of a South African series of banknotes, first issued in 1992, using the five largest animals living in the wild parks of South Africa (stage 2 in figure 3.41), bringing the accompanying name of "The Big Five" (stage 3). Subsequently each of the five denominations received a theme (stage 4) and a name (stage 5), like rhinoceros (10), African elephant (20), lion (50), Cape buffalo (100) and leopard (200). Similar, the theme "The Sea" of the new Norwegian banknotes is subdivided

into five subthemes (Norges Bank, 2014a; 2014b), like “the sea that binds us together” (50), “the sea that feeds us” (200) and “the sea that carries us forward” (1000).
Although ‘One banknote for Europe’ is a first order communication message, the forerunner of the European Central Bank, the European Monetary Institute (EMI), had another message in mind and proposed "Ages and Styles of Europe". Each denomination should represent a historical period (Age) and a building representing that age (Style). Subsequently seven denominations were planned, which should represent eight design periods. This was solved by attributing two styles tot the 100 euro, Baroque and Rococo. In 2007, the Dutch were asked about these style periods (De Heij, 2007). In a trial, it became clear that not all respondents understood what is meant with a style period and the question was changed from an open to an aided question. The themes were mentioned in random order to prevent any bias. Still, this was not helpful enough and respondents became slightly irritated: “You can stop with summing up the periods, I really do not know” was the remark heard several times. Asking for the art representing the historical theme of the euro 50, the correct answer “Renaissance”, was only given by 1 %, while 82 % of the respondents could not identify any style period for this banknote model. The euro 5 note scored a little better: 2 % gave the correct answer of the “Classical” period, while 77 % could not attribute any style period to this note.
Further details on measurements done on the communication messages of euro banknotes are provided in section 6.5.

In the *design briefing* for the 1996-design contest, the designers could read that euro banknotes could be designed within two categories, “Ages and Styles of Europe” and “Abstract/modern”. In both cases, the designs should also embody a *cultural* and a *political message* (European Central Bank, 2003). No suggestions were made for a political message, except for the self-referential "should embody a political message that's readily acceptable to all European citizens". The Austrian winner of the design contest, Robert Kalina, fulfilled this requirement by introducing two mottos, one for the front and one for the reverse. On the front “Openness to others” is reflected by the windows and doors, showing some light coming through. The motto applied to the reverse is “Bridges linking people”.
It is not only the theme of the euro banknotes which remains unknown, the two political messages incorporated in the architectural constructions displayed are not recognised either. It is not clear that the windows and doors are open and represent "openness to others". The message of "bridges linking people" is also difficult to understand; there are no people on the bridges and the bridges do not connect anything, they are ‘floating in the air’.

5. Name giving of the banknotes

Nicknames of banknotes often find their origin in the banknote’s colour (UIF 1) or in connection to the main image (UXF 4). The colour of the banknote is optimised for value recognition, as UIF 1 prevails over communication messages (UIF 4) and also over connecting to the main image (UXF 4). When banknotes carry similar images, the back may provide a name to the note, although examples are unknown. The reverse of the GBP 20 issued in 2007 pictured Adam Smith (1723-1790); however, this note did not become a ‘Smithy’. Although the reverse of a banknote may provide a nickname, like in the case of “green back” (subsection 3.2.3), there are no examples known that an image on the back provides a nickname.
On the Australian banknote series, first issued in 1994, the name of the person’s portrait was not mentioned on the banknotes. As of 2002 these names have been added to the print. There are no studies published whether this measure increased the knowledge of the Australians of the persons portrayed on their banknotes.

COMMUNICATION MESSAGES OF EURO BANKNOTES			
Message category	**Theme**	**Subtheme**	**Design element**
1. Euro banknote	Euro	Euro in different languages	Word EURO Word ΕΥΡΩ Word EVRO (ES2) Currency symbol €
		European Central Bank	Abbreviations BCE ECB EZB EKT etc. Signature
		European Union	Flag European Union Ring of starts
		Europa	Map of Europe
2. Cultural messages	Ages and Styles of Europe (Historical period and architectural feature)	5 - Classical	Front: Window or gate Back: Bridge
		10 - Romanesque	
		20 - Gothic	
		50 - Renaissance	
		100 - Baroque and Rococo	
		200 - Iron and glass	
		500 - Modern	
	Europa, the Greek myth	Portrait of Europa. Image taken from a vase in the Louvre, Paris.	Portrait in watermark Portrait in hologram.
3. Political messages	Openness to others	Open window or gate	Window or gate showing light coming through
	Bridges linking people	Bridge	Bridge
4. Authenticity features	Feel	Tactile relief	Tactility of letters (ES1)
	Look	Watermark	Gate or window (ES1) Portrait of Europa (ES2)
		Security thread	Security thread
		See-through register (ES1)	Numeral
		Secure window (ES2)	In foil stripe: 20, 50, 100 and 200
	Tilt	Hologram	Foil stripe (ES1: 5, 10 and 20) ES2: all denominations
			Foil patch (ES1: 50, 100, 200 and 500)
		Iridescent band	Iridescent band: ES1: 5, 10, 20 ES2: all denominations
		Colour changing numeral	Colour changing numeral ES1: 50, 100, 200, 500
		Rolling bar (ES2)	Emerald numeral (also colour changing)
5. Motto	The Euro. Our Money	-	-

Figure 3.42
Breakdown of the communication messages of euro banknotes (De Heij, 2015c). Nine themes are identified and 23 subthemes.
ES1 = Euro Series 1 = Ages and Styles of Europe.
ES2 = Euro Series 2 = Europa Series.

6. Name giving of the public authenticity features

A specific category is name giving to authenticity features for public use. This is a relevant topic, as name giving will assist people in their search for public features. When name giving is not planned during the design process, it must be done after the design is ready, usually by the central bank's communication department.
People are not familiar with 'foil patch' or 'hologram' and call it 'glitter thing' (De Heij, 2007). The same holds for 'see-through register', 'security thread' and 'tactile elements'. Linguistic determinism tells that people may only remember a name when this is meaningful to them. Furthermore, people will remember an image better when its name is printed near the image (Peek, 1972). In 1989, these two principles were applied to the Dutch banknote designs. The word "KLAPROOS" (poppy flower) was printed next to a see-through register in the NLG 25/Robin (figure 1.2b). Also, the names of other public features were printed close to the corresponding feature.

When denomination numerals are used for public features, name giving can only be done by adding adjectives like in the "magic number", the "chameleon number" and the "glittering number" as was done for the Swiss banknotes shown in figure 3.32 (Swiss National Bank, 1995).
Suggestions are made for themes/slogans to support the communication on public features, like 'Look for the colour', 'All features in a row' and 'Look under the bridge' (De Heij, 2007). Of all messages incorporated within the first series, people seem to have picked up that the euro is about money and not about people; the word euro, synonymous for money, is frequently printed. The first suggestions to bring some life into the euro banknotes were proposed in 2001 by De Nederlandsche Bank. A female portrait, representing the Renaissence, is incorporated in the watermark of DNB's proposal for an emergency banknote for the 50 euro. The suggestion to replace the buildings in the watermarks of the euro by a face was later repeated by Eagleman (2017). A "portrait of Europa", a figure known from Greek mythology, was proposed by Reinhold Gerstetter, the designer (Currency News, 2013). A similar type of image was already applied in his 1996-proposal for a 5 euro banknote (European Central Bank, 2003). The portrait of the watermark design was after a portrait of Europa on a phase in the Louvre.
In 2013, the Europa Series was introduced, increasing the complexity of the communication messages of euro banknotes. The Europa Series uses the same themes as the previous series of Ages and Styles of Europe and added a portrait of Europa to the watermark and and a similar portrait was displayed in the 'transparent window', part of the foil feature. Figure 3.42 provides a breakdown in message category (1), theme (2), subtheme (3), and design element (4). This figure learns that there the communication messages of euro banknotes incorporate 9 themes and 23 subthemes.

Messages of banknotes will be more successful when the designers follow the "Six Principles of Sticky Ideas" (Heath and Heath, 2007), listed on the left in figure 3.43. First advice is to make the core of the message clear by keeping it simple. Applied to a banknote this would mean just one theme and avoid complexity, as listed on the right side of the figure. A message should also have elements of surprise. People should be able to memorise the message; in the case of banknotes by figurative images and name giving. For a banknote design to be credible, a new design should not be too deviant from previous designs, it should have one foot in the past, as will be elaborated on in section 5.7. Adding emotional content will make banknote designs less flat. By following the letters, A-R-U-B-A (figure 3.33a), people act on a short story.

OVERALL COMMUNICATION ASPECTS OF BANKNOTES		
Six Principles of Sticky Ideas		**Applied to banknote design**
Heath and Heath (2007)		
1. Simple	Make the core clear	Just one theme, avoid complexity
2. Unexpected	Grab people's attention by surprising	Element of surprise
3. Concrete	Make people memorise it	Figurative images. Name giving.
4. Credible	Make people believe it	Keep one foot in the past
5. Emotional	Let people care about it	Add emotional content
6. Stories	Let people act on it	Little story

Figure 3.43
Overview of the Six Principles of Sticky Ideas and the suggestions made to improve the overall communication aspects of banknotes.

3.5.2 Communicating public features

After the Swiss had published information leaflets (section 3.4), others followed this example and in the 1980s most central banks accompanied the release of a new banknote design with an information leaflet for the public at large.
The motto 'feel, look, tilt' was developed in 2001 to accompany the introduction of the euro banknotes (European Central Bank, 2001; 2004b). The motto echoed the perception of a banknote by the human senses, respectively by vision and touch, as will be discussed in more detail in section 5.2. An advantage is that this motto is independent of the design of the features. For example, the communication of the see-through register was reduced to a simple 'look'. An ambiguous instruction as look may refer either to *look-at* or to *look-through* (subsection 5.2.1). Furthermore, feel and look refer to the senses of respectively touch and vision, but tilt refers to handling, to moving and rotating the banknote and during these movements the observer must look-at the feature.

In the years that followed, the motto 'feel, look, tilt' was copied by several others, like the central banks of Korea (2006), Chili (2006) and Mexico (2007) (De Heij, 2007).
One may question how effective the feel, look, tilt motto is. In 2017, many Dutch respondents didn't use this instruction, as reported in a qualitative study to the effectiveness of public authenticity features on euro banknotes (Van der Horst et al., 2017). Many respondents did not hold the watermark to the light, instead they checked the watermark by rubbing their fingers over the area. When it comes to the tactile ink, respondents don't seem to notice the tactile ridges on the edges of the models of the Europa Series.

One of the first articles on the development of public information on public features was by Van Erve (1990). Since then it seems that the knowledge of public education on banknote features has not developed much further, until Eagleman (2017) stated that public awareness campaigns on public features are bound to fail, as people will not put effort in learning on authenticity features. This statement is confirmed by studies on the public attitude in the Netherlands towards an authenticity check, as will be reported in subsection 6.4.5.
Central banks reassure the public on executing an authenticity self-check, like in case of the promotional text accompanying the issue of the latest USD 100 banknote (Bureau of Engraving and Printing, 2013): "It only takes a few seconds to check the new $ 100 note and know it's real". In Europe "It is very easy to check a euro banknote (…) by using the simple feel, look and tilt method." (European Central Bank, 2013d). The Bank of Japan is more reluctant and "advises the public to familiarize themselves with the security features" (Bank of Japan, 2004).

Central banks may tell that their banknotes are easy to check, but the public may have another opinion. Authenticity features are often not understood without explanation. However, using banknotes, people don't have this information at hand. Dutch banknotes arrived in two steps at such an instruction. First, in 1986, the traditional *penal code text* was replaced by a text, listing all places along the Dutch coast with a lighthouse, matching to the theme of the NLG 250/Lighthouse (figure 1.1d). This text aimed at the public, instead of counterfeiters. In a second step, this text was further developed to a brief usage description of four public features present in the Abstract Series (figure 1.2). The bottom line of this text is printed in micro-lettering, a feature in its own right. It reads: This text should be readable. Altogether an example of a use-centered design approach. The sequence of the text lines was based on public feedback received from the biannual surveys (subsection 2.10.3). The best-known feature was referred to in the last line (the watermark); the least-known feature (see-through register) in the first line. To give an example, the memory text on the NLG 10/Kingfisher (1997) reads in English (De Heij, 2000):

> "Seen against the light, the precisely fitting elements form a stickleback.
> The text beside the watermark can be read through a magnifying glass.
> The ink-layer on the front can be felt.
> The kingfisher in the watermark has light and dark tints."

3.6 Conclusions on User Interface Functions

The following four User Interface Functions of a banknote have been described: recognising value (1), handling (2), checking authenticity (3) and receiving the communication messages (4). The banknote designer must create design solutions for all four, which is not plain sailing.
UIFs also relate to bank machines processing banknotes, except for UIF 4, as machines ignore communication messages (section 2.7).

UIF 1 - Recognising value

The fewer denominations there are, the easier it will be to recognise the value. On average, banknote series include six denominations, which seems to be too many. From a user perspective, three banknote denominations are sufficient. In addition, a banknote series may include a fourth denomination, to serve the saving function of banknotes. Such a high value note should be designed differently.
A good basis for a denomination structure for cash is 0.2 - 0.5 - 1 - 2 - 5, with the nucleus unit one. A series of banknotes should first make use of denominations based on multiples of ten, like 10, 100 and 1,000. Secondly 5, 50 and 500 units are welcomed and thirdly banknotes of 2, 20 and 200. There is a public demand for high denominations and such a denomination could be designed along other lines as the values used for daily payments.
The note-coin boundary does not have to be the centre of the denomination structure. The note-coin boundary should be the lowest ATM denomination. A coin and a banknote of the same denomination should be avoided.
The banknote's value is recognised by its denomination features. Denomination features should be optimised for the visually impaired, consisting of three subgroups, the colour blind (1), poor sighted (2), and blind (3), all in need of different features. Once optimised for the visually impaired, normal sighted will, so is the expectation, not have any problems with instant value recognition.
Denomination features are numerals (1), colours (2), main images (3) and sizes (4). Numerals should have a character height between 15 mm and 22 mm. These numerals must be printed both in positive and in negative, respectively a dark numeral on a light background and a light numeral on a dark background. This background must be homogenous, delivering a high contrast with the numeral (PCR > 70 %).

Colour is the first feature being recognised when a banknote is handed over. Once in focus, the main image and the numerals will further contribute to instant value recognition. Vivid colours are relevant to colour blind, delivering maximum colour differences between neighbouring denominations. Poor sighted will also profit from an optimal colour scheme.
Main images taken from different image categories support the denominating process, creating a relation between instant value recognition (UIF 1) and the main image (UXF 4).
Most people take a banknote with their right hand, covering the right half of the banknote. For optimal value recognition, the numeral and main image should therefore be positioned on the left.

The most relevant denominations to the blind are the payback banknotes. Size differences of these denominations are usually too small to be a reliable indicator of the banknote's value. Based on best practices, size differences should start at 7 mm. Because of Weber's law this increment should grow with 1 mm for higher denominations, respectively to 8 mm, 9 mm and so on.
Tactile structures should be different for each denomination and may further assist value recognition by the blind. Furthermore, the blind would rather not use any device to denominate a (payback) banknote, as they don't want to attract attention. Still, additional devices to denominate a banknote are appreciated, like a Cash Test device and an app available on a smartphone.

UIF 2 - Handling

The first forms of paper money could be as large as a sheet A4. Over time banknote sizes have become smaller to fit into people's wallets.
Design solutions for handling functions of modern banknotes should serve its users when they store banknotes in their devices like a wallet, and when they insert banknotes into machines. These two usage situations led to the following three handling features: orientation (1), single note height (2) and variable lengths (3). Proposals are made to improve all three handling features on user-friendliness.
Banknote sizes may not fit properly in a wallet, being either too small or too large.
A horizontal orientation is optimal in a billfold wallet, while a vertical orientation will assist the public when they feed a banknote into the slot of a banknote payment machine and will also assist retailers when they store the notes vertically in their cash drawers. Banknote designs following this concept of a public wallet front and a cash drawer/banknote acceptor back, have not yet been created.
To fit properly into the wallet of people, the banknotes' length should not be longer than 160 mm and its height should not exceed 75 mm. Furthermore, wallet types are changing. Instead of billfold wallets people tend to keep banknotes in card cases and etuis for smartphones.
Modern banknotes are handled by automatic processing and therefore a single note height is most efficient, a clear trend. A single note height is the most user-friendly solution, as it prevents skew and eliminates additional feeding instructions. To match with modern wallets, this height should be between 65 and 75 mm. Many central banks provide their banknotes a single note height, the euro being one of the exceptions.

UIF 3 - Checking authenticity

Paper money was introduced in the Western world in the 12th century. To merchants' paper money was an improvement of the handling function of coins (UIF 2). The trade-off was the introduction of an authenticity check, adding a third user function (UIF 3). Other user functions of early banknotes were value recognition (UIF 1), experiencing identity (UXF 1) and keeping confidence (UXF 3). Over time, more user functions have been added, bringing the total to ten as presented in the Upid-Model. Also, the number of primary user groups increased, from merchants to six user groups for modern banknotes (public, retailers and counterfeiters, all with and without banknote machines).
These developments had consequences for the number of authenticity features. The first banknotes (1661) incorporated 5 features and the first euro banknotes (2002) over 35. In general, 3 authenticity features per user group are sufficient, which would bring a total of 18 authenticity features. The reason why banknotes carry twice as many authenticity features as needed, is that new features are added without abandoning existing ones. The trend of more authenticity features in smaller banknotes puts banknote design under pressure.

The modern merchant is the retailer, receiving on average about 120 banknotes per day, while the public uses one or two. More than the public, the retailer is key to prevent the spread of counterfeited banknotes. Detection of counterfeited banknotes by retailers is left to the market; retailers must decide for themselves, which gives rise to confusion. UV features are at the end of their life, but still promoted. Instead central banks should, so is the author's advice, accommodate the retailer, for example by offering a dedicated automatic device in different price-quality ratios.

The public perceives authenticity features as a means to make it difficult for the counterfeiter. Up to the 1980s, people were not bothered with authenticity features of banknotes. To inform the public was to inform the counterfeiters, so was the basic thought. This policy started to shift in the mid-1980s, when banknotes could be copied with a colour copier. A few years later, banknotes could be reproduced at home, and central banks had to react. The spread of home-made banknotes had to be stopped and the public had to act as the first line of defence. Central banks introduced *public features*, accompanied with information leaflets. To date, an authenticity self-check is becoming less needed and people are losing their interest. People don't check banknote's authenticity, as they correctly believe that:

- Banknotes obtained from ATMs are genuine,
- Retailers check banknote authenticity before issuing them to customers,
- The change is in low denomination notes which are usually not counterfeited.

The search process to authenticity features can be supported by search features. People found about twice as many public features when these features are pointed out by search features.

Future feature development should be based on user needs. A split within a banknote series by its public features is not appreciated. Furthermore, it seems that public features based on look-through and tilt are are not well appreciated either; most likely features based on feel and look-at will serve the public better.

UIF 4 - Receiving a communication message

The fourth user function is receiving a communication message (UIF 4). Instead of a focus on the receiver, messages on are sender-oriented. The euro banknotes are an example.
When a banknote is used for a payment, communication messages are irrelevant. Still, people may be interested in the motto, themes, subthemes and images displayed. They should also be able to do an authenticity self-check (UIF 3) and therefore, they should be aware of the public features. Other user functions also contribute to the final interpretation of the banknote's message, like experiencing identity (UXF 1) and connecting to the main image (UXF 4). Judging aesthetics (UXF 2) and evoking emotions are also part of it.
In the light of an increasing number of user groups to be served by smaller banknote sizes, it is remarkable that almost half of the front's surface is used for communication messages like the main image, which does not contribute to the three most relevant UIFs (except that a main image may contribute to instant value recognition).

Central banks incorporate too many messages and most of them do not seem to come across. A complete communication plan for a series should be ready *before* the designs are filled in. A series should have *one* theme to which all communication messages relate. Starting point of such a plan is an identity description, part of UXF 1.
Denominations should receive a subtheme and a name. Public authenticity features should be part of one 'sticky message' of the banknote's subtheme, offering a memory aid like a little story or a mnemonic.

Beauty is in the eye of the beholder.
Margaret Wolfe Hungerford (1855 - 1897)

CHAPTER 4
USER EXPERIENCE FUNCTIONS

4.1 Introduction

The question answered in this chapter is: What is known about the User Experience Functions of a banknote?

Designers will know "Beauty is in the eye of the beholder", meaning that the perception of beauty is subjective. Margaret Hungerford is credited for this slogan, the earliest kept in printed form dates back to 1878. Rutherford's principle is relevant to 'judging aesthetics' (UXF 2), one of the six User Experience Functions.
When a new design is issued, people are interested in the UXFs. The unveiling of a new banknote is therefore an optimal moment to get the public's attention. However, after a while people get used to the new design and they rely on the UIFs. Ideally, the UXFs should contribute to the optimal functioning of the UIFs.
Literature on User Experience Functions of banknotes is limited. The focus is usually on just one of the experience functions. The identified literature is listed according to the Model of Use-centered Design of Banknotes:

UXF 1 - Identity is a broad topic and subject of study in several knowledge domains. There is a general publication on the development of the identity of banknotes, zooming in on the banknote's role of nationalist iconography and state propaganda (Lauer, 2008). The currency iconography of modern nation-states has become the subject of a growing interdisciplinary literature, much of it published in *Political Geography.* The identity study on the banknotes of the Taiwan Dollar is an example (Hymans and Fu, 2016 and the references therein). Identity descriptions are available of British banknotes (Hewitt, 1994), the euro (Helleiner, 2002) and Canadian banknotes (Gilbert, 1998).
UXF 2 - Aesthetics of consumer products have been object of study (Bloch et al., 2003). Broader studies relate to the domains of fine arts, design, fashion and architecture. Even more widely, such studies can be seen as part of philosophy. Aesthetics may also be object of study from the perspective of psychology, involving studies of the human mind and emotions in relation to the sense of beauty.
UXF 3 - Confidence in banknotes has been measured in Canada, first in 2004 and thereafter repeated annually (Taylor, 2006). Several design factors may contribute to experience confidence. First, a more pleasing banknote design will enhance trust, because of the *halo-effect* (Van der Horst, 2016). Second, familiarity to the authenticity features contributes to people's confidence (Masuda et al., 2015). A related study on coins demonstrates that a larger coin is associated with a higher value (Kirkland and Flanagan, 1979).
UXF 4 - Main images on banknotes were subject of study by Monestier (1993), presenting banknotes from all over the world. However, Monestier did not provide any analysis.
UXF 5 - Sustainable banknotes are a broad topic and several aspects have been object of study. Studies report on the life of banknotes (e.g. Koeze and Van Gelder, 1985, Pearson, 2012) and on the banknotes' *Life Cycle Analysis* or LCA (e.g. Wettstein and Lieb, 2000; European Central Bank, 2013d). Central banks replaced cotton based banknotes by polymer, and report studies on the *environmental impact*. The first was the Reserve Bank of Australia (Hardwick, 2002), followed by the Bank of Canada (Marincovic et al., 2011) and the Bank of England (Shonfield and Smith, 2013). In 2013, the first paper on *Corporate Social Responsibilities* appeared (Banknote Ethics Initiative, 2013).
UXF 6 - A chip in a banknote has been described in 2004 (Perron et al., 2004). Technical concepts using a smartphone for an authenticity check on banknotes have been published (e.g. Lohweg, 2012).

A working prototype, called “Phoney” is presented by DNB in 2014 (Van der Woude and Geusebroek, 2014) and released in the Netherlands in 2015. A description of the final app is provided by Van der Woude (2016). An overview of different apps for banknotes is provided by Currency News (2016a).

This chapter reports on the six User Experience Functions experiencing identity (section 4.2), judging aesthetics (section 4.3), retaining confidence (section 4.4), connecting with the main image (section 4.5), expecting sustainability (section 4.6) and linking to information technology (section 4.7). Characteristic design elements are reviewed from a usage perspective. This chapter ends with conclusions on UXFs of banknotes (section 4.8).

4.2 Recognising identity (UXF 1)

Identity topics have been reviewed in “Designing banknote identity” (De Heij, 2012) and includes the report of a dedicated study done in 2011 on how the Dutch perceive the identity of euro coins and banknotes. The study was well received among banknote designers, and the author was invited to provide a summary in their magazine (De Heij, 2013b)
Identity is a broad term as demonstrated by the literature on identity topics. A person has a *personal identity* and a society a *collective identity*, topics within the domain of sociology and cultural anthropology. The collective identity of a nation is known as the *national identity.* In general, central banks aim for a reflection of the national identity as an essential ingredient of the *product identity* of their banknotes. They apply *identity features* like national symbols, such as the coat of arms, flags, maps and currency symbols. One more example is an unprinted border, present on the euro banknotes, a characteristic design element which refers to the former banknotes of the twelve countries, which merged in 2002 their banknotes into the euro banknotes (De Heij, 2012).
The picture shown in figure 4.1 demonstrates how product and national identity may come together. When in 2016 King Bhumibol of Thailand died, the Thai people expressed their grief by showing collectively their banknotes, displaying the deceased king.

Experiencing identity

Figure 4.1
Thai people using their banknotes to express their grief about the death of King Bhumibol Adulyadej (14 October 2016). Image: Rungroj Yongrit/EPA.

Subsection 2.2.1 explained that products are split in consumer and utility products. Both categories contribute in different ways to people's identity; consumer products contribute to people's personal identity and utility products to their collective identity. Utility products are perceived as 'our products' and for such products Anholt (2007) coined the term "nation brand". A banknote design may also appeal to visotors like tourists, the banknote in its role as the *business card of the country*.
Next to the product identity there is the *corporate identity,* the identity of the manufacturer. Studies on *corporate identity* became popular in the 1950s and refer to what people perceive, feel and think about a corporation (Clifton et al., 2009). In case of utility products, the corporation is usually a Governmental Organisation (GO), like the organisation of the national railways or the national central bank. A corporate identity in banknote design is present through the name of the central bank, the place of issue and the signature of the Governor. Buildings of central banks have been - and still are - regularly used (e.g. the building of De Nederlandsche Bank on the back of the NLG 25, 40 and 60, issued in 1921; the building of the Banco de España on the ESP1,000, issued in 1971). One more example is the building of the US Treasury, featuring the reverse of the denomination of USD 10. On the front, this banknote depicts Alexander Hamilton (1755-1804), the first Secretary of the Treasury. Governors are sometimes displayed, like a former President of DNB, Willem Cornelis Mees (1813-1884), pictured on the NLG 25/Mees (figure 5.15d).
Similarly, an outstanding banknote design will receive national and international recognition and its *design identity* will contribute to the national identity. An example of a clear shift in the identity of a banknote design is reported for the Taiwan New Dollar (TWD); the 'Chinese imagery' has been replaced by a 'Taiwanese imagery' (Hymans and Fu, 2016).
Central banks seem to become more interested in the foundation of the identity of banknotes. Recently, the Bank of Canada consulted the Canadians on an identity description (Bank of Canada, 2014), which is the start of the design process (subsection 3.5.1).

This section continues with a review on national identity (subsection 4.2.1), symbolism (subsection 4.2.2), a uniform and a hybrid identity (subsection 4.2.3), before ending with the latest insights in an identity description for banknote design (subsection 4.2.4).

4.2.1 National identity

A banknote design is defined by the sum of all design elements applied. Several of these elements will contribute to the national identity of the banknote. Furthermore, to ensure the identity of their banknotes, central banks usually select a fellow citizen to be the designer.
National identity as expressed on banknotes has developed from an *inward-looking policy to emphasise national identity* (topic 1) to an *outward-looking policy* (topic 2).

1. Inward-looking design policy to emphasise national identity

An inward-looking policy was typical for the 19th century with the establishment of nation states. Banknotes often played a role in constructing a collective national identity, as for example in 1861, in the case of a single currency for the USA (original: Potter, 1879, as provided by Helleiner, 2002, page 189):

> "Every citizen (...) who is supplied with such a currency - a currency which will be equal to gold through every foot of our territory, and everywhere of the same value, with which he can travel from Oregon to Florida and from Maine to New Mexico, would feel and realize, every time handled or looked at such a bill bearing the national mark, that the union of these states is verily a personal benefit and blessing to all."

Indeed, currencies were used to strengthen a national identity. Not only in the USA, but also in other countries. The first Italian banknote designs followed the adage of Massimo d'Azeglio (1798-1866), in 1861 formulated as follows: "We have made Italy, now we have to make Italians" (Zelizer, 1994). Similar, the banknotes issued in France had to support the transition of "peasants into Frenchman" (Gilbert and Helleiner, 1999; Helleiner, 2002). In line with these predecessors, Delanty (1995, page 8)

stated “The situation is not very different today: Europe has been united, but those elusive citizens, the Europeans have yet to be invented”. Symbols of the euro and European identity have been investigated (Kaelberer, 2004), although such studies do not provide specific design guidance. There is a need for such advice, as phrased by former ECB-president Jean-Claude Trichet (2004):

> “The euro banknotes should help to contribute to a greater sense of belonging to one European community, over 300 million people are carrying the euro in their pockets and this will bring Europe closer to them.”

In several publications, the ECB underlined that the euro is “a tangible symbol of integration” (e.g. European Central Bank, 2008).

The name of the central bank is one of the design elements contributing to the national identity of a banknote. A central bank’s name can often be explained by history, which may create today some confusion, like in case of the Canada, where the “National Bank of Canada” is a commercial bank, the “Bank of Canada” is the central bank. In Greece, the status of a bank is also not always that obvious. The “National Bank of Greece” is a commercial bank and the “Bank of Greece” is the Greek central bank. Others avoided the word ‘national’ and/or the word ‘bank’, like respectively in case of the “State Bank of Pakistan” and the “Monetary Authority of Singapore”. One more example is the “Federal Reserve System” in the USA (FRS). Name giving explains why the FRS refers to their paper money by “notes” instead of “banknotes” (figure 4.2a). Later the term *central bank* was introduced, like in case of the “European Central Bank” (ECB). Since the Euro Area is not a nation, this is an appropriate name. However, this clarity disappeared when it was decided to print cryptical abbreviations on euro banknotes (figure 4.2b).

Portraits of head of states are a specific category of banknote design elements contributing to a national identity. Morocco, Thailand and the United Kingdom are examples of such an identity policy. A variant within this category are portraits of former heads of state or the nation’s founding fathers, as displayed on denominations issued in China, India and South Africa (figure 4.3a). There is a special place for Queen Elisabeth II of Great Britain. Since 1954, her portrait is present on more than 100 banknotes of the Commonwealth of Nations. When in 2016 the Queen's portrait appeared on a new banknote of ASD 5 (figure 4.3b), criticism was heard from Australian citizens, as the Queen is no longer felt to be a representative of the modern Australian identity (The Guardian, 2016b).
Central banks may emphasise banknote identity not only for the citizens, but also to the outside world; indeed using the banknote as the business card of the nation. Studies on the national identity on banknotes are rare, examples are the iconography of Scottish banknotes (Penrose and Cumming, 2011) and of Taiwanese banknotes (Hymans and Fu, 2016).
Early examples of countries involving their best artist in banknote design are Alfons Mucha (1860-1939) in Czechoslovakia and Eliel Saarinen (1873-1950) in Finland. A more recent example is Robert Oxenaar in the Netherlands (section 1.1).

Central banks may underline their national identity on banknotes by exceptional flora, fauna or culture, in some cases aiming for tourists. Figure 4.4 provides two examples of such banknote models, one from Rwanda showing zebras (1978) and one example from Nicaragua, displaying culture (2014). Other nations issuing banknote models within the category of ‘flora and fauna’ are Aruba, Bermuda, Costa Rica, Cook Islands Sri Lanka and Uganda.
Other examples of an outward looking design policy emphasising the national identity are banknote designs which support the Olympic Games, depicting the Olympic Stadium (China, 2008) and a snowboarder (Russia, 2014).
When asked for themes on banknotes, people often suggest themes fitting in an outward looking design policy. In 1997, Canadians suggested “children at play” (section 2.10), resulting in ice hockey playing children on the back of the CAD 5, issued in 2002. Asked for themes for new euro banknotes, the Dutch mentioned the Eiffel tower, the Acropolis and the tower of Pisa (De Heij, 2007), indeed major touristic attractions of the Eurozone, as will be elaborated on in subsection 6.9.2.

Indication of the identity of the nation

a)

b)

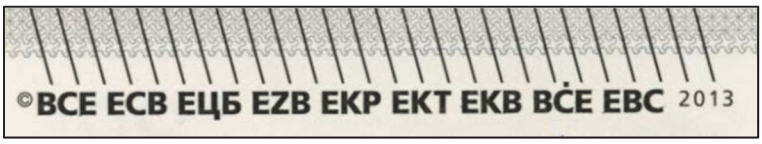


Figure 4.2
Indications of the issuing authorities of USD and euro banknotes.
a) USD 1, issued in 1929. The United States of America.
b) EUR 5, issued in 2013. Nine abbreviations of the letters ECB.

Inward looking identity

Nelson Mandela (2012)

a)

Queen Elisabeth II (2016)

b)

Figure 4.3
Two examples of an inward looking national identity.
a) ZAR 100, issued 2012. Featuring Nelson Mandela (1918-2013).
b) ASD 5, issued 2016. Featuring Queen Elisabeth II from Great Britain.

Outward looking identity

Fauna of Rwanda (1978)

a)

Culture of Nicaragua (2015)

b)

Figure 4.4
Two examples of outward looking national identity.
a) RWF 100, issued in 1978. Zebra's.
b) NIO 10, issued in 2015. Costume and dance.

4.2.2 Backward and forward-looking symbolism

Banknote designers often incorporate *symbols* in their designs. Such icons represent an idea, a belief, an action or an entity (De Heij, 2015c). Typical examples have already been introduced in subsection 1.3.3, like a coat of arms, the national flag, a geographic map, heraldic beasts and motifs relating to folklore. Mythological symbols are also applied in banknotes, like the *caduceus*, the staff of Hermes, the god of financial gain and commerce in the Greek mythology (Mercury in the Roman mythology). Another is the *cornucopia* or horn of plenty, a container overflowing with wealth, represented by flowers, nuts or other edibles. Figure 4.5 provides some examples.
A well-known banknote full of symbolism, is the reverse of the one dollar banknote in the US, issued in 1937 (figure 4.6). A single book has been written just about the symbols used on this banknote, elaborating especially on the meanings of the truncated pyramid (Ovason, 2004). A French banknote issued in 1942 is a late example of a banknote overloaded with icons, like the *victory statuette*, the *ear of corn* and *olive branches* (figure 4.6b). A special category of symbolism is the representation of a nation by female symbols, like Marianne symbolising France and Britannia the United Kingdom (figure 4.7).
In modern societies, traditional symbolism is experienced as paternalistic, as already introduced in subsection 4.2.1 for the latest Australian 5-dollar banknote featuring Queen Elisabeth II. An alternative form of symbolism is *forward looking symbolism* (De Heij, 2015c). Such an approach is expressed by the two examples shown in figure 4.8. The first is the preferred entry of the European public at the time of the euro banknote design competition (1996) with the theme 'Diversity in Unity' (figure 4.8a). The theme of the second example is 'sitting together at the European table' by Thom van Enckevort, prepared in 2008 (figure 4.8b).

4.2.3 Uniform and hybrid identity

The previous subsections introduced the options between respectively an inward and outward looking identity policy (subsection 4.2.1) and between a backward and forward-looking symbolism (subsection 4.2.2). This subsection continues with a third variable relevant to the user function of recognising identity, a *uniform identity* or a *hybrid identity,* (De Heij, 2012).

In case of a uniform identity the front and the back of a banknote represent the same nationality. A banknote model may also express two identities, like the identity of the collective organisation on one side ant the identity of a member organisation on the other side, an example of a hybrid identity. Euro coins received such a hybrid identity, expressing a European identity on the common side of the coins and a national identity on their national side (note that there is no front or reverse of euro coins). This hybrid identity of the euro coins is appealing to the Dutch. They like the concept of a 'foreign euro coin' in their wallet, a coin coming from Cyprus, Germany or Portugal (see section 6.2).
A hybrid coin policy does have a drawback. With so many different variants the perception of counterfeited coins is hindered. It is also difficult to recognise fantasy variants, coins showing designs that are not officially issued. This was precisely the argument for the euro banknotes not to introduce a hybrid banknote identity; too much variations would make it difficult to recognise a mimicked banknote. These two user needs are an example of conflicting design requirements. On the one hand the public appreciates coin variations because of its hybrid identity, on the other hand retailers don't like variations of coin designs.

A related topic to hybrid designs is the *referring design* of coins and banknotes, as both are part of one means of payments, cash. An example a harmonised identity between coins and banknotes is found in Brazil. Their national symbol is the "Efígie da República" is applied to coins as well as on banknotes (De Heij, 2012; 2016b; 2017). Another example is Azerbaijan, where the motifs on modern coins correspond to the motifs on modern banknotes.

Typical symbols

Cornucopia Horn of plenty	Caduceus Staff of Mercury	Seal Federal Reserve System	Flag European Union

a)

b)

c)

d)

Figure 4.5
Typical symbols as used on banknotes.
a) Horn of plenty (Image: public domain).
b) Staff of Mercury (Roman) or Hermes (Greek) (Image: public domain).
c) Seal of the United States Federal Reserve System.
d) Flag of the European Union (Image: public domain).

Banknotes full of symbolism

a)

b)

Figure 4.6
Two banknotes full of symbolism.
a) United States, 1 dollar banknote, reverse. The original reverse was issued in 1929. President Franklin D. Roosevelt (1882-1945) initiated in 1937 a new design for the reverse, introducing the Great Seal and the symbols of Freemasonry.
b) France, 5,000-franc banknote, front. The original version dates to 1939 and an upgrade was issued in 1942 (http://banknoteindex.com). Symbols used are the victory statuette, ear of corn and olive branches. Designer: Sébastien Laurent (1887-1973).

Female symbols on banknotes

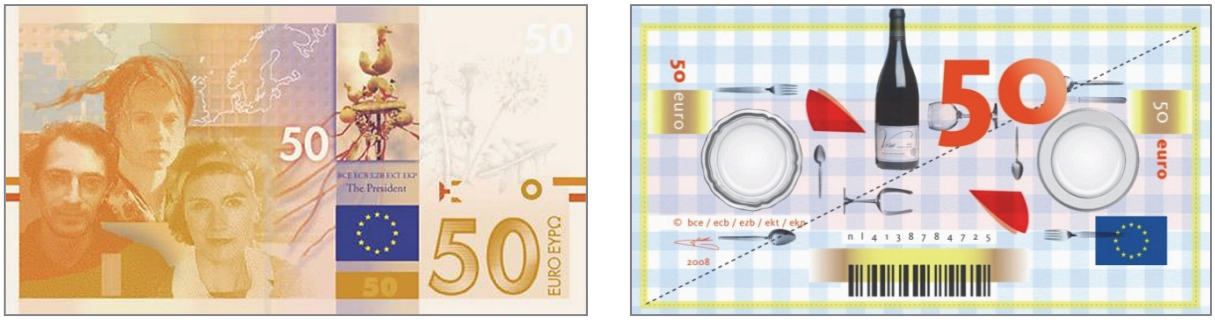
Germania, 1909 | Marianne, 1922 | Britannia, 1930 | Europa, 2013

a) b) c) d)

Figure 4.7
Female symbols on banknotes.
a) Germania on a banknote of 100 Reichsmark, issued in 1909.
b) Marianne on a 5-franc banknote, issued in 1922. Marianne has continuously adorned French coins since 1793. Marianne also appears on the national side of the French euro coins.
c) Britannia on a banknote of one pound, issued in 1930. Britannia has continuously marked British banknotes since their first issues in the 1690s. In her right hand, Britannia holds an olive branch. The shield shows the crosses of Saint George and Saint Andrew.
d) A portrait of Europa is used for the second series of euro banknotes, the Europa series (2013). The image of Europa is taken from an ancient vase and is used for the watermark and a part of the foil.

Forward looking symbolism

Diversity in Unity | Sitting together at the European table



a) b)

Figure 4.8
Examples of forward looking symbolism on euro banknote designs.
a) Theme: Diversity in Unity. Design: Maryke Degryse, Belgium (1996). Preferred entry of the public of the euro banknote design competition 1996.
b) Theme: Sitting together at the European table. Design: Thom van Enckevort, Netherlands (2008).

When it comes to identity, the design of euro coins and banknotes are referring to each other, but not harmonised. There is a currency indication in Greek on euro banknotes, but not on the coins (De Heij, 2007). Furthermore, the map of Europe on the coins is different from the one on the banknotes; Norway and Iceland are not present on the first coins, but are - obviously - present within the map of Europe on the euro banknotes. These inconsistencies are the result of two different authorities involved in the design of euro cash money, respectively the European Union being responsible for the design of the coins and the European Central Bank for the design of the euro banknotes.

4.2.4 Identity description

An identity description has been introduced at the start of an overall communication plan (subsection 3.5.1). Two examples of identity descriptions are provided in figure 4.9, respectively descriptions of former Dutch guilder banknotes and euro banknotes. The identity description of the Bank of Canada is of recent date, supported by 79 % of the Canadians, and an example of users delivering feed forward input for a next series of Canadian banknotes (Bank of Canada, 2014):

> "A series of bank notes is a unique opportunity to represent Canada. Each series depicts new visual content so that, over time, the diversity of Canadian society, culture and achievements are celebrated. Bank notes:
> • promote Canada and Canadians - our values, culture, history, traditions, achievements and/or natural heritage;
> • are clearly identifiable as Canadian through the use of symbols, words or images;
> • are meaningful to Canadians today and for years to come; and
> • evoke pride and confidence in Canada."

The identity of a banknote can be defined in relation to foreign banknotes by *positioning diagrams* (De Heij, 2012). A positioning diagram is a two-by-two matrix, first created in 1968 for the Boston Consulting Group by Bruce D. Henderson (1915-1992) and therefore also known as BCG-matrix or Boston-matrix. An example is provided in figure 4.10, displaying two qualitative variables of a series design: colour and main image. This analysis unveils that most banknote designs are representatives of the upper left quadrant, as they show different colours combined with images taken from one image category. The provided example also unveils that the lower right quadrant is a rather unexplored area, the concepts of similar colours and different images. More positioning diagrams may be constructed using other sets of variables. Several examples are provided by De Heij (2012), like positioning diagrams covering:

- Objects - Life,
- Historic - Future,
- Serious - Happy,
- Local orientation - Open to others,
- Directive, institutional - Neutral, non-institutional.

Identity descriptions

NLG (1995)

Reflect a Dutch, or at least not un-Dutch character.
Create a little smile.
Be contemporary.
Not show living individuals.
No bias to religion.
Be dignified.
Be dynamic (as opposite to static).
Be representative of its value.

a)

Euro (1996)

Be visual attractive.
Be clearly identifiable as European.
Embody a cultural and political message.
acceptable to all Europeans.

b)

Figure 4.9
Two examples of an identity description for a new banknote design.
a) Identity description of former guilder banknotes (De Heij, 2000). Guilder design by Jaap Drupsteen.
b) Identity description of the euro (European Central Bank, 2003). Euro design by Robert Kalina.

Positioning diagram

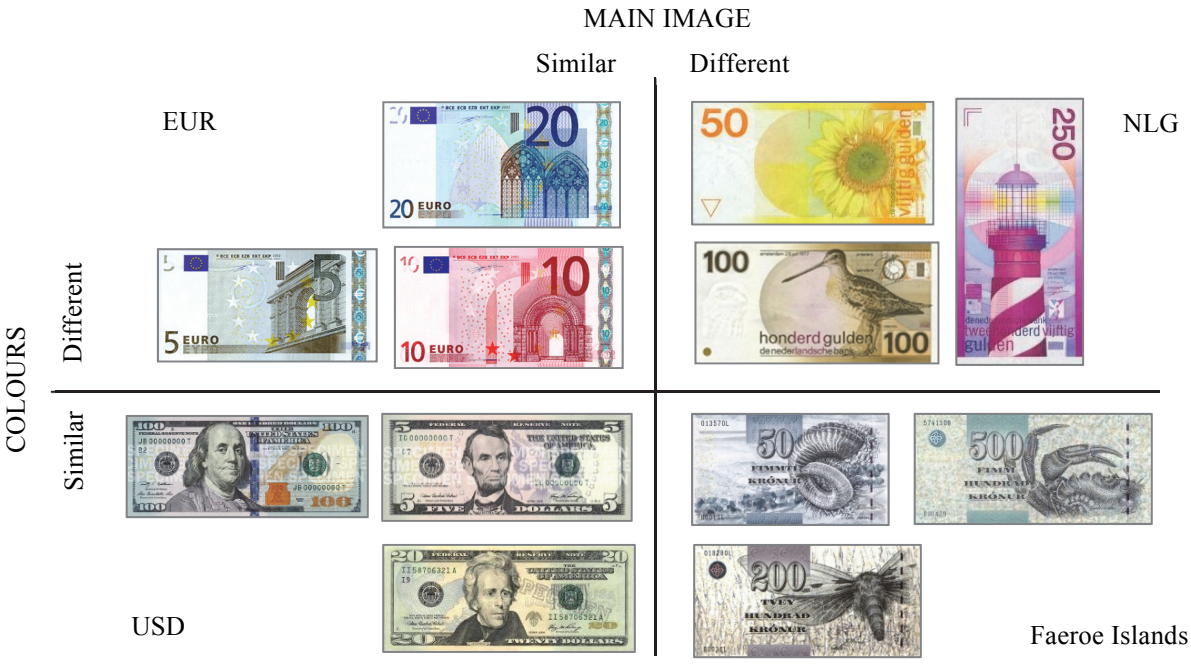


Figure 4.10
An example of a positioning diagram for banknotes, using 'main images' and 'colours' as variables. Clockwise the quadrants show euro banknotes (issued in 2002), Dutch guilder banknotes (first issued between 1981 and 1986), banknotes form the Faeroe Islands (first issued between 2001-2005) and US dollar banknotes (first issued between 2004-2013). It is difficult to find examples for the quadrant different images and similar colours.

4.3 Judging aesthetics (UXF 2)

At the launch of a new banknote design central banks may have their own aesthetic judgements when they present their banknotes as “everyday pieces of art” or as “a distinctive aesthetic quality” (Salmon, 2011). Such statements on the public’s appreciation are usually not backed up by any studies. Questions on banknote aesthetics were for the first time part of public survey in the Netherlands in 1981 and have been repeated since every two years.
An appropriate definition of aesthetics is: “Aesthetics are a set of principles concerned with the nature and appreciation of beauty (Dictionary: Van Daele, 2016). This definition suggests that aesthetics has many facets.
Success of consumer products is usually represented in the *product lifecycle* (subsection 1.3.2). Usually this plot turns out to be a clock bell curve and can be divided in four phases: introduction (1), growth (2), maturity (3) and decline (4). In case of banknotes the product lifecycle cannot be measured by the number of banknotes sold. Instead, “banknote appreciation curves” represent the users’ satisfaction. These curves turned out not to be a clock bell curve, but a constant, as will be elaborated on in section 6.7 on measuring judging aesthetics (De Heij and Koeze, 1988; De Heij, 2002a; Randsdorp and Zondervan, 2015).
Banknote aesthetics are also related to *emotions*, illustrated by a statement made by the Dutch design manager Julius Vermeulen (born 1953) on the occasion of the issuance of the 50-euro banknote of the Europa Series (NOS, 2017): “Beautiful euro banknotes can contribute to a positive feeling about the European Union”.
Guarding the aesthetic quality is one of the main tasks of the banknote designer. During the process of *origination*, the preparation of a banknote design for production, the banknote designer cooperates with several specialists, like a watermark die cutter, an engraver and a hologram designer (De Heij, 2017). The banknote designer should assure that all the delivered partial designs fit into the artistic composition.
An *aesthetic advisor* may assist the central bank in safeguarding the aesthetic quality. Up to 1986 an aesthetic advisor was consulted by DNB for feedback on the design quality of a new design proposals (Bolten, 1999). The role of an aesthetic consultant was in 1983 partly replaced by the appreciation scores of the issued banknotes, delivered by DNB's biannual public poll (subsection 2.10.3).
The selection of the winning design for the first series of euro banknotes was guided by a jury, which included expertise on design aesthtetics. At the time of the design processes of the second series of euro banknotes an aesthetic advisor was not consulted.

Beautiful banknotes will, so is the thinking, receive more attention than ugly ones. Following the adage of “Attractive things work better” (Norman, 2013), it is relevant to create aesthetically pleasing banknotes. Therefore, a first decision of a central bank should be to design a series, as series design will lead to higher appreciation scores than solitary designs (subsection 1.3.4).
Second, interest in banknote features is a four-stage process, as described in figure 4.11. People tend to pay attention to valuable things and therefore the first stage is the recognition of value, the banknote should not look like a cheap *coupon*. In a second step, people will judge whether the banknote is beautiful or ugly. The third stage concerns interest, does the banknote have an appealing theme? Subsequently, in stage four people may become interested in the public features.

The decision diagram shown in figure 4.11 brought the first thoughts on a correlation between banknote aesthetics (box 2) and knowledge of public authenticity features (box 4) and was investigated for Dutch banknotes (Koeze and De Heij, 1984; Den Butter and De Heij, 1985). The assumption was that the more people appreciate a banknote, the more they would spontaneously recall pictorial elements, text elements and authenticity features. In 1983, the first object of study was the NLG 100/Snipe (figure 1.1c). A total of 18 correlation tests was carried out on *appreciation* and *knowledge*, and a significant correlation was reported for 16 of the 18 tests done. Respondents unable to recall a single picture element of the NLG 100/Snipe, hardly appreciated this banknote (36 % beautiful). This score increased to 63 % beautiful for respondents recalling one design element. In case respondents recalled two elements, this score increased to 72 % and the few respondents who recalled three or more picture elements reached a score of 83 %.

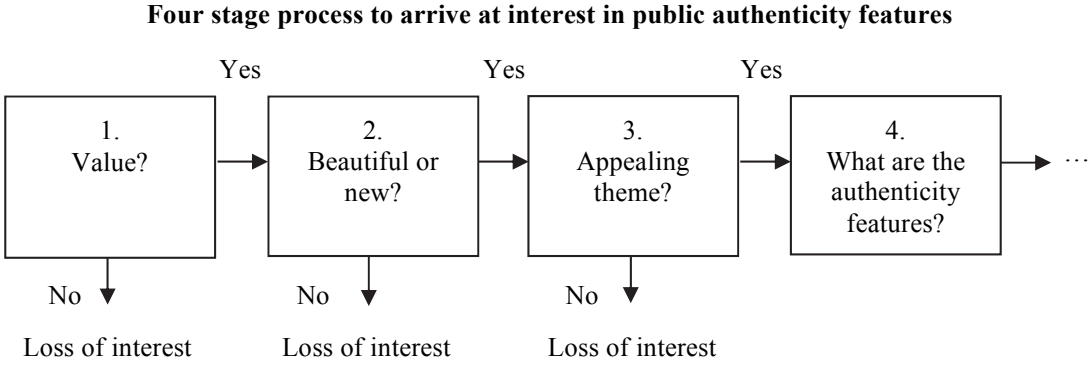


Figure 4.11
A decision diagram of people's first interest in the public authenticity features of a banknote. The first reaction to a new banknote will be is it valuable, is it a banknote? Secondly the new design must appeal within an instant, otherwise people lose interest.

In 1985, a similar test was done, which brought less evident findings than in 1983; correlations between appreciation and knowledge were confirmed for 11 of the 18 correlation tests conducted. Moreover, the correlation between appreciation and knowledge of the pictorial elements diminished in the case of the NLG 100/Snipe.
Respectively in 2015 and 2017 the study on the correlation between *appreciation* and *knowledge* of authenticity features was repeated for the euro banknotes (Randsdorp and Zondervan, 2015; Klöne and Zondervan, 2017). The contracted agency was explicitly asked to focus on possible correlations. However, no correlations were identified between appreciation and knowledge of authenticity features, texts elements or image elements. The outcome was not in line with earlier findings and even the reverse was reported. Respondents dissatisfied with euro designs knew more features than people who appreciated euro designs. A possible explanation is that people being more knowledgeable on banknotes also noticed the relatively low aesthetic quality of the euro banknotes (section 6.7).

Another relation is the banknote's *appreciation* and the *opinion* people may have about banknotes. When people have a positive experience about a person or product, they also tend to contribute other positive properties to this person or product, although there is no evidence. This stereotype of 'what is beautiful is good', is known as the *halo effect*, coined by Edward Thorndike (1874-1949). The halo effect also applies to banknotes (Van der Horst, 2016). The more people appreciate a banknote of 50 euro, the higher is their confidence in its authenticity. One more halo effect is reported by Van der Horst: the more beautiful banknotes are, the cleaner they are thought to be.

4.4 Retaining confidence (UXF 3)

Modern banknotes are 'just a piece of paper' that people trust (subsection 1.3.3). Confidence in banknotes is grounded on trust in the currency. Governors of central banks often refer to this function, like in 2015 when the President of the ECB said that the new banknote "will reinforce the trust that the 338 million citizens across the euro area place in their banknotes" (European Central Bank, 2015b). The issuance of a consistent banknote series will contribute to trust (subsection 1.3.4) and so will a high design quality of the individual banknotes. Furthermore, a high production quality will contribute to confidence in banknotes, just as a good quality of banknotes in circulation. The inclusion of visible *register marks* may emphasise the high standards of the banknote printing (De Heij, 2008c). Obviously, the level of counterfeited banknotes is one more aspect, although it is unknown upto which level of counterfeiting people will keep confidence in their banknotes; even in Somalia, people have some trust in the counterfeited banknotes (subsection 3.4.1).

This section continues with four pillars of trust (subsection 4.4.1), legal aspects (subsection 4.4.2) and confidence features (subsection 4.4.3).

4.4.1 Four pillars of trust

Confidence in banknotes is fostered by the following four pillars: trust in the currency (topic 1), trust in a piece of paper (topic 2), trust in the issuing authority (topic 3) and trust in the banknote's authenticity (topic 4).

1. Trust in the currency

Trust in banknotes starts with trust in the currency's economy. Hyperinflation undermines trust in the currency, when banknotes become almost worthless in a relatively short period of time, forcing people to pay with piles of banknotes instead of using single banknotes. There have been many examples, like Germany (1921-1924), Hungary (1946), Israel (1984), Argentina (1994), Zimbabwe (2009) and Venezuela (2016).
Moderate inflation levels may also influence people's trust in the currency. Moderate inflation levels usually lead to the need for a higher denomination, followed by another one. Over time, the currency unit becomes a hundredth, thousandth or a ten thousandth part of its original value. Subsequently, the decision of a currency reform is made, referred to as 'dropping zeros'. Such a monetary reform implies a new currency name and a new currency code, and includes the design of a new series of banknotes. Another aspect of the trust in the currency is the validity of old banknotes withdrawn from circulation. In general, old models remain redeemable after a notice period. In case of the Dutch guilder this was 30 years; gulden banknotes can be exchanged at DNB for euro banknotes up to the year 2032. No period is specified in case of the US dollar and the euro banknotes, the reason why the banknotes of 500 euro will remain valid (subsection 2.4.3).

2. Trust in a piece of paper

The intrinsic value of a banknote is close to zero, people have trust in 'just a piece of paper'. Banknotes are *fiat money*, pieces of paper guaranteed by the government, opposite to *commodity money*, which is money whose value is associated with the material of which it is made, like coins made of silver or gold (Nelson, 2009).
People mutually have to trust each other that another person will accept a piece of paper for payment. This belief made that to Adam Müller (1779-1829) a national currency is an expression of the *inner spiritual unity* of the nation. George Simmel, already introduced in subsection 2.4.1, observed the *quasi-religious faith* that underwrites the material form of money (Helleiner, 2002). Others emphasised that trust in banknotes is built on *rationalisation* and *mystification* (Lauer, 2008).

3. Trust in the issuing authority

In the early days, banknotes were issued by commercial banks. When banknotes kept circulating, the bank would earn more money. Obviously, when people trusted their banker, they would not return their banknotes. However, when banknotes were not covered for coins made by silver or gold, the bank went bankrupt. The first was Stockholms Banco, after being in business for seven years; the bank was liquidated. However, the Swedish Parliament wanted to continue the banking activity in Sweden, and therefore a 'state bank', a central bank, was established in 1668. Other nations followed, like Great Britain (1694), France (1800) and the Netherlands (1814). Central banks became the sole issuers of banknotes. Coins remained the responsibility of the state, ordering their coins at several mints.

Unlike Europe, in the early 19th century, commercial banks in the United States of America were free to issue banknotes. As any bank could issue banknotes, the bank's name was usually clearly identified (UXF 1). Special catalogues were prepared, listing all existing banknotes. The free banking era reached great heights. At its peak around 1858 about 7,000 different types of valid notes - and 5,500 varieties of fraudulent notes - were circulating and this pinnacle was never surpassed (Clain-Steffanelli, 1975).

In 1862, the authorities in the USA replied to this 'disordered currency system', with the introduction of *Legal Tender Notes* (UXF 3), as will be elaborated on in subsection 4.4.2. Rather than guaranteeing the right to be exchanged for gold, these notes proclaimed to settle all "taxes and other public dues". The umbrella organisation of several central banks in the United States came in 1913, with the establishment of the Federal Reserve System.
Also in Europe central banks underlined that their banknotes could be trusted, by printing on the notes 'banknotes issued by the state' or words of similar meaning. Two examples are "Biglietto di Stato" and "Reichskassenschein", both dated 1882, banknotes of respectively Italy and Germany.
With the arrival of central banks, private banks could no longer issue banknotes, although there are some exceptions like in the United Kingdom and in China (Hong Kong).

Something else that undermines the trust in banknotes is the discontinuation of denominations. Withdrawing banknotes on a short notice will bring mistrust, as was recently the case in India. In 2016, the Indian government announced, on a short-term notice, the discontinuation of the INR 500 and 1,000, respectively about USD 7 and 14 (Wadhwa, 2017). These two denominations accounted for roughly 85 % of all money in circulation. The move intended to curb corruption and eliminate counterfeit notes, meanwhile Indian citizens lost trust in their banknotes. Also in 2016, the Venezuelan government announced the sudden withdrawal of the VEF 100, the most widely used denomination, to stop transnational gangs hoarding cash. The announcement of the ECB to stop the printing and issuing of the 500 euro (subsection 2.4.3) is another measure in this context. However, the issued 500 euro banknotes will remain valid and can be exchanged for other denominations at the central banks of the Euro Area.

4. Trust in the authenticity of banknotes

A fourth component of trust in banknotes is the authenticity of the banknotes in circulation. The public's confidence in banknotes can be measured, as periodically done since 2004 in Canada. This score is reported as a "Confidence Index", and is the result of several variables like trust in the currency's value, the visibility of retailers verifying banknotes and the perceived number of counterfeited banknotes in circulation.
Triggered by this Canadian example, the topic was in 2005, implemented in DNB's biannual opinion poll (De Heij, 2010a; 2016d). Although the measurement methods are different, the Canadian and Dutch scores can be compared with each other, as will be presented in subsection 6.8.1. This subsection demonstrates that *confidence scores* in banknotes are high and stable, a remarkable finding, as the number of counterfeits in both countries is not stable. In Canada, the level of counterfeits reached its top in 2004 of 470 ppm and dropped in the following years to below 50 ppm (Moxley et al., 2007), while in the Netherlands the number of counterfeited euro banknotes started in 2002 with zero and increased over the years to an average of around 50 ppm.

The probability that the public will receive a counterfeited banknote is low (subsection 3.4.1) and interest in an authenticity self-check is on the decline (subsection 6.4.5). Banknotes withdrawn from an ATM can be trusted and people witness retailers checking banknotes by devices. As a result, the confidence of the public in banknotes is high (subsection 6.8.1). However, people should be alert on mimicked banknotes in specific places, like markets, fairs, cafés and bars (subsection 3.4.1). Furthermore, people may trust their ability to detect a counterfeited banknote; studies show that people are quite capable of recognising a counterfeit within a pile of banknotes, as will be elaborated on in subsection 5.4.3.

People's trust in banknotes could be influenced by the communication of the number of counterfeited banknotes. For example, by a press release, the ECB reports every half year on the counterfeits discovered; in the first half of 2013 a total of 317,000 counterfeit euro banknotes were withdrawn from circulation (European Central Bank, 2013b). One may reconsider such a communication policy. First, such a figure is not meaningful to an ordinary citizen. Second, most likely, it will not contribute to foster confidence in the authenticity of euro banknotes.

4.4.2 Legal aspects

Legal measures may support confidence in banknotes. Knapp (1905) investigated the legal status of banknotes. Knapp supported the case for legal tender, declaring that the soul of money is not economic, but legal and political. Only the state can provide the necessary backing for such a guarantee, so is the opinion of Knap. Money is that which is accepted at government pay offices. Weber (1920) countered Knap's statement, pleading that the state should adapt to market usage and should also accept other means of payments than cash. Weber's vision became reality, for example, in the Netherlands, as since the years 2000s income tax can no longer be paid by cash. Furthermore, in 2014, cash was completely banned from public transport in London for being cheaper and speeding up boarding times. Public transport in Amsterdam made a similar decision, mainly based on safety arguments for their employees; as from 2017 cash payments are, gradually, banned.
This subsection continues with a review of legal tender (topic 1), followed by aspects of a two-sided market (topic 2) and the range of denominations (topic 3).

1. Legal tender

Cash is legal tender, the right of the public to pay in cash. Already in the 18th century, banknotes became legal tender, like in Sweden (1745) and France (1790). The French paper money was called *assignats*, as they were not issued by a bank, but by the state; the French central bank was established in 1800 (subsection 4.4.1). An example of an assignat is shown in figure 5.15b. By 1796, ten times more assignats were issued than their collateral, which reduced people's trust in these notes, also in the Netherlands, which was in these times occupied by the French. When DNB issued their own banknotes in 1814, the Dutch had little trust in this new variant of paper money (Grolle, 1991). In the Netherlands banknotes received the status of legal tender in 1904.
About forty years earlier, in 1862, the authorities in the US introduced Legal Tender Notes in response to the excess supply of private banknotes (subsection 4.4.1). This measure had impact on the design of the new dollar bills; a relevant part from the Legal Tender Act was printed on the reverse of the notes (figure 3.9d). One may print 'promise to pay to bearer' on a banknote, but legislation is needed to make banknote legal tender.

With cash being replaced by digital means of payments, legislators are investigating whether a new and technology-neutral regulation may be needed, like for example in Sweden (Segendorf and Wilbe, 2014). In 2015, the Danish government proposed to allow selected retailers the right to refuse cash, such as restaurants and gas stations (Pymnts, 2015; Scholten, 2017b). Also in the Netherlands, the situation with legal tender is reviewed, using the meaningful title "Paying Cash. Right or Favour?" (Scholten, 2015; 2017a).

2. Two-sided market

Two parties are involved to agree on a payment instrument, a *payer* and *recipien*t (or *payee*). It is usually the payer proposing a payment instrument, which is in general accepted by the recipient, usually a retailer. This payment situation is characterised as a *two-sided market*. An example is the option between 'cash' or 'cards' offered to car drivers entering a gasoline station, shown in figure 4.12a.
When the payee offers a choice, like cash or cards, people may feel more secure to pay with a banknote, as they may think: If a payment by debit card is not possible, I will pay with cash. The reverse may also be the case, poeple may opt for a cash payment, if their debit card banknote payment is unsuccessful.
Another example is provided by figure 4.12b, where people buy *tokens* to be used at a festival, either by cash or cards.
Retailers may restrict the type of payment instruments to be used, which is their right of *contractual freedom.* In such cases, they should indicate their conditions in advance, for example, by stickers as shown in figure 4.13a.

In general, Dutch consumers may use their favourite payment instrument and the Dutch means of payments are valued by a score of 7.7 on a scale from 1 to 10 (Jonker et al., 2012). This appreciation mainly reflects the satisfaction for the *easiness* to make a payment. Dutch retailers appreciate the local means of payments even slightly higher, scoring 7.8. Both, public and retailers are least satisfied with the charges for terminals for bankcard payments, although fees hardly affect the overall valuation of the payment instruments used.

3. Range of denominations

Central banks may offer a range of cash denominations, but people may not want to use all. Denominations beginning with 2 are unpopular, such as the USD 2 and the JPY 2,000, as introduced in section 3.2.1. Furthermore, people may avoid the bottom and/or top of the range of denominations. The Euro Area is an example, where some member states abolished the 1 and 2 eurocent. When low denominations are no longer efficient, sales receipts can be rounded to units of 0 and 5. In the early 1980s, Dutch retailers started rounding of total prices by 0 or 5 cent (one gulden was 100 cent). The official decision was made in 1983, bringing total cost savings for retailers and for society, in these days calculated at about 30 million euro per year.
Another user advantage is that cash transactions take less time, appreciated by both the retailer and their clients. Finland never introduced the two lowest euro coin denominations, as they were judged to be inefficient (although they were minted for the collectors market). In the Netherlands, these two coins were abolished in 2004 (figure 4.13a). More recently, Belgium, Ireland and Italy also aim for the abolishment of the two low euro coin denominations.
Retailers may further limit the acceptance of cash payment instruments by announcing non-acceptance of 100, 200 and 500 euro (figure 4.13a). Restrictions on the use of cash are also imposed in other countries, like in case of a large fast food service provider in the USA, observed by the author, notifying their customers by: “Sorry we don’t take US currency above 20 dollar” (2014). Two more observations concern public transport, setting a limit of 20 Canadian dollar in Montreal (2014) and 20 euro in Amsterdam (2014), before the decision was made to eliminate cash completely (2017).

Two sided market for payment instruments

Cash or cards? Cash or PIN?

a) b)

Figure 4.12
People are left a choice on how to pay. Examples of two-sided market for payment instruments.
a) At this gasoline station, the client may choose between two different methods of payments (Luxemburg, 2012). Image: De Heij.
b) People may buy tokens - in Dutch munten or coins - to pay for a drink at the North Sea Jazz Festival (Rotterdam, 2016). People may pay by cash or PIN. Image: De Heij.

Limited range of cash payment instruments

Limited use of euro denominations

a)

Cards only

b)

Figure 4.13
Banknote denominations in the Netherlands do not have to be accepted in the Netherlands when shops indicate on their front door that they do not accept banknotes.
a) Sticker indicating a limited range of cash denominations. No acceptance of 1 and 2 eurocent, no acceptance of high banknote denominations and no acceptance of collector coins. Although the sticker suggests otherwise, the Dutch may still offer 1 and 2 eurocent for payments, if they end up to 0 or 5 eurocent. Image: Platform Detailhandel, 2013.
b) Bakery in Amsterdam accepting cards only, 2012. Image: De Heij.

4.4.3 Confidence features

The very first banknotes already incorporated confidence features, features with the task of supporting trust, like the name of the issuer, the currency indication, date and place of issue, signatures, seals, numbering and a national symbol. Over time, the first authenticity features lost their technological lead and could be reproduced, like a watermark, a gravure and banknote numbers. However, such outdated authenticity features are maintained as they contribute to confidence. In terms of the Upid-Model, original authenticity features lost their authenticity function (UIF 3) and became a confidence feature (UXF 3). Others, like the banknote number remained an authenticity feature, but when banknote numbers were automatically read by cameras, they received a new role (subsection 4.7.1).

Early banknotes were validated by one or more signatures from their issuer (Heinonen, 2009b). Stockholms Banco issued banknotes with various number of signatures, up to eight, while the Bank of England started in 1694 with handwritten notes on bank paper and signed by one of the Bank's cashiers (Bank of England, 2017). Whether a signature is legally required depends on the regulations of the respective country. Russian banknotes carry no signature (Lönnberg, 2008). The signature is not in front of people's memory; based on recall, about 1 % of the respondents mention a signature as an authenticity feature (figure 6.16). A signature is a confidence feature, a reproduced signature is identical to the original. Still, about 7 % of the Dutch think that a signature is an authenticity feature (Van der Horst et al., 2016).

Signatures are either *fixed* or *variable,* respectively representing the *approval* of the design or representing the *guarder* of the value of the currency (De Heij, 2006a; 2012). An example of fixed signatures are the former Dutch gulden banknotes and an example of variable signatures are found on the banknotes of the US dollar and the euro.
An advantage of variable signatures is that a new central bank governor may sign existing banknotes. However, within a use-centered design policy fixed signatures are preferred over variable signatures for several reasons. First, variable signatures are at odds with the idea that all banknotes are similar (UIF 3). Variations in genuine banknotes reduce the heuristic quality (subsection 5.4.1), making it

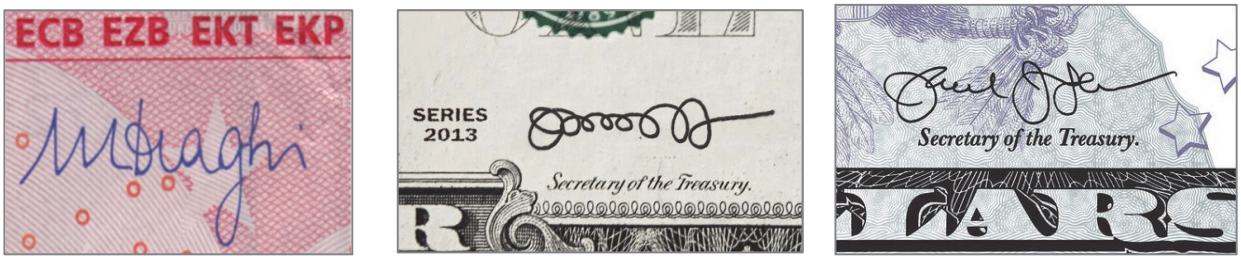
more difficult to spot differences between a genuine and a reproduced banknote. Furthermore, variable signatures must be masked out for image processing, making authentication of banknotes more complex and less reliable.
In case of Dutch banknotes, the approval date on banknote designs was antedated at least twice, when a sitting president 'gave away' his signature to the appointed successor. The design of the NLG 50/Sunflower was approved by president Jelle Zijlstra in 1981, but received the signature of president Wim Duisenberg and was antedated on 4 January 1982, Duisenberg's first working day as president. In turn, president Duisenberg approved the design of the NLG 10/King Fisher in 1996, and left the signature to president Nout Wellink; the banknote model was antedated on 1 July 1997, the date of Wellink's appointment.

The third president of the European Central Bank, Mario Draghi, made a remarkable adaptation of his signature. He didn't put his regular signature on the euro notes, but wrote his name in his own handwriting (figure 4.14a). A similar situation occurred in 2013 in the United States, when president Obama asked his new appointed Secretary of the Treasury, Jack Lew, to adapt his unusually loopy signature, shown in figure 4.14b (Lindsey, 2013). Lew responded to his president and in June 2013 the first 5 dollar notes appeared with an adapted signature (figure 4.14c).
Banknote users are probably served best when the signature is fixed. It is the author's opinion that the most meaningfull use of a signature would be the date of approval of the first printing proof.

Register marks have been listed in the introduction of this section, relatively small design elements which may serve as confidence features, as they may provide a banknote a 'technical look'. Register marks in the Dutch banknotes were prominent design elements (De Heij, 2008b), but usually such elements are hidden. One of the reasons, so is the opinion of the author, is that banknote producers would rather not display their production tolerances.

Adapted signatures

Handwritten | Signature without trust | Adapted signature



a) b) c)

Figure 4.14
Examples of adaptation of signatures on banknotes (Images: public domain).
a) To make the signature better readable, Mario Draghi wrote his name on the 10-euro banknote (2012).
b) Original 'Loopy' signature of Jack Lew on a one dollar banknote (January 2013). The position of Lew's signature is above 'Secretary of the Treasury'.
c) Adapted, more dignified signature of Jack Lew on five dollar (June 2013).

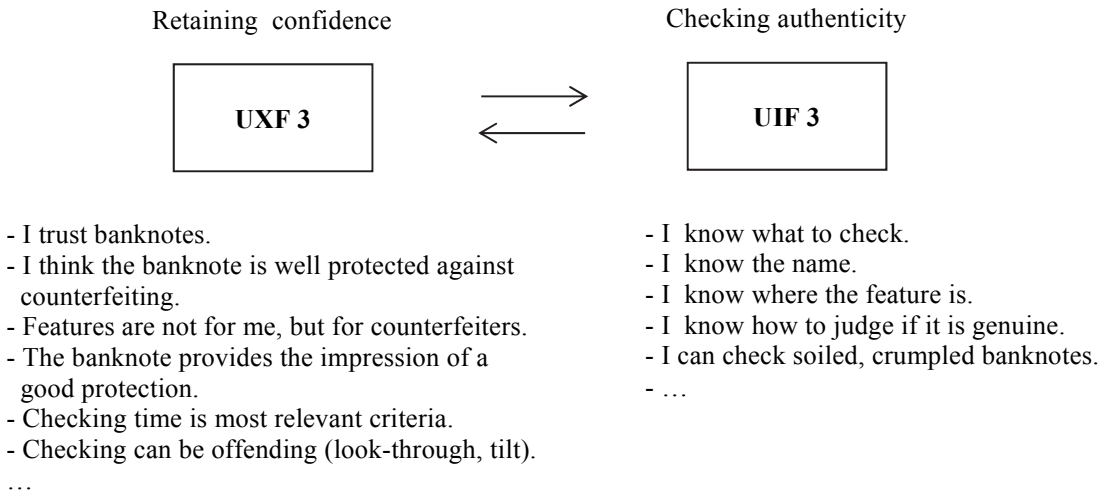


Figure 4.15
User requirements related to UXF 3 versus user requirements related to UIF 3.

The connectedness between an authenticity self-check (UIF 3) and confidence (UXF 3) is one of the strongest relationships between user functions, so is the author's speculation. Confidence of Canadians in their banknotes remained stable up to 500 ppm (subsection 6.8.1), suggesting that confidence in banknotes prevails over the probability to receive a counterfeited banknote.
People have an increased confidence in the genuineness of banknotes, and as a consequence they are less-and-less willing to do an authenticity self-check (subsection 6.4.5). As a result, confidence in the authenticity of banknotes is on the rise and the need for an authenticity self-check tends to fall.
Instead of making UIF 3 more complex, banknote designers should shift their focus from UIF 3 to UXF 3, illustrated by figure 4.15 (De Heij, 2016d; Currency News, 2016b).

4.5 Connecting with main image (UXF 4)

The previous sections introduced respectively recognising identity (section 4.2), judging aesthetics (section 4.3) and retaining confidence (section 4.4). This section continuous with exploring the banknote's main image. Two topics, relevant for the design of a main image are presented in chapter 5 on perception, respectively connecting with a main image (subsection 5.3.3) and perception aspects of a main image, be it a portrait, a bird or a building (subsection 5.4.4).

Early banknotes are typographic designs and do not carry any images (subsection 1.3.3). Although images have been used before 1850, their breakthrough was during the Prosperity period. The communication message of the images in these days was to illustrate that the use of banknotes would contribute to economic wealth, to the prosperity of the nation (see the example in subsection 3.5.1). Modern banknote designs opt for portraits, national flora, national fauna or cultural heritages. People like to know what these main images represent, who or what is it? Images displayed may lead to a positive or negative reaction. Emotions play a role, as experienced by the Swiss central bank in 2005, when they presented their winning design, which displayed on one of the denominations an embryo (figure 5.8b). The Swiss public protested and the central bank decided to drop this winning series and opted for the runner up (Swiss National Bank, 2007).
A *smile scale* may assist the design of the main image of a banknote (De Heij, 2007). This scale is an ordinal ranking of existing banknotes on their perceived appearance of cheerfulness, from sad to grumpy and happy.

A banknote's message can be misinterpreted and become part of a public debate on political correctness, as was the case in the Netherlands in 1953 (Bolten, 1999). In 1949, the Dutch Parliament discussed about a small catholic cross on a church depicted on the NLG 25/Salomon. The discussion was initiated by a Protestant clergyman.
Another category of public interest is when there is something wrong or when main images have been manipulated during the design process. When in 1996 the designs for the euro series were unveiled, the design of the 5 euro showed an image of an ancient pontoon bridge in India, which was rapidly changed for a European type of bridge (European Monetary Institute, 1996). In 2012, the Bank of Canada had to apologise for replacing an Asian woman on a proof print of the 100 Canadian dollar by a non-Asian looking person (Bank of Canada, 2012).

A special category of main images on banknotes are female portraits. Up to the early 1970s, women from the realm of science or arts were only incidently displayed. In some cases, a queen featured a banknote, like Queen Victoria (1819-1901) on North American banknotes and the (mother) Queen Emma (1858-1934) on a Dutch 20-guilder banknote issued in 1939. Queen Elisabeth II was first portrayed in 1954 on Canadian banknotes and appeared in 1960 on the British pound. Female portraits also appeared on the German banknote series issued in 1960, portraits selected from gravures by Albrecht Dürer (1471-1528). Similarly, a series of Danish banknotes, issued in 1972, featured four female portraits and one male portrait painted by Jens Juel (1745-1802); one of these banknotes is displayed in figure 5.15f.
A more equal balance between the portrayal of women and men on banknotes was triggered by women empowerment, which came to great heights in the 1970s. In 1985, a portrait of Raden Adjeng Kartini (1879-1904), a pioneer of women's rights for Indonesians, appeared on an Indonesian banknote of 10,000 rupiah. The Germans followed in 1990 with the issuance of the first model of a new banknote series displaying both women and men. The German series was the first to divide females and males equally over the denominations, alternating the portrait of a woman and a man. A portrait of Clara Schumann on the 100 D-Mark was printed on a background of bright colours delivering this banknote the impression of an open, transparent and happy note, befitting a trustworthy German currency (figure 5.15h).
In 1994, the Swiss followed with a new series of banknotes displaying both men and women. In 2004, a Japanese banknote of JPY 5,000 was issued featuring a female portrait, the writer Higuchi Ichiyō (1872-1896). South Korea followed in 2009 with a female portrait of the calligraphist Shin Saimdang (1504-1551) on the KRW 50,000.

In 2013, the discussion of a balance between male and female portraits was redone in Great Britain (The Guardian, 2013), when the Bank of England announced that they planned to replace Elizabeth Fry (1780-1845) on a 5 pound note by Winston Churchill (1874-1965). This implied that there would be no other woman than Queen Elizabeth II on British banknotes. In a reaction, Jane Austin (1775-1817) was selected for the future GBP 10.
Almost half of the Canadians (46 %) would also like a more equal representation of gender on their banknotes (Bank of Canada, 2014c; Pollara, 2014). On Women's Day 2016, 8 March, the Bank of Canada announced that a woman will be depicted on the new series and invited the public to make suggestions (Bank of Canada, 2016).
New banknotes planned for the USA, dubbed "modern money", will also include portraits of women (Lew, 2016). Eleanor Roosevelt (1884-1962) is planned for the reverse of the USD 5 and Harriet Tubman (1823-1913) for the front of the USD 20. Alexander Hamilton (1755-1804), the first secretary of the Treasury, will remain on the front of the 10 dollar note and five women's suffrage activists are planned on the reverse. In 2020, the concept designs will be unveiled in conjunction with the 100th anniversary of the Constitution's 19th Amendment, which granted women the right to vote.

4.6 Expecting sustainable banknotes (UXF 5)

Banknotes have been produced for over 350 years and during the first three centuries environmental aspects did not receive much attention. In the 19th century, the USA employed “Ivory Black”, a black ink used for banknotes containing ivory. When ivory became expensive, it was replaced by other bones (McCabe, 2016). To date, ivory is a forbidden ingredient, a measure to prevent nature. By tradition, central banks focus on the basic usage requirements as listed in figure 3.25.

Figure 4.16 provides an historical overview of the various topics of sustainable banknotes. The first central banks which have been active in this field are mentioned.
When it comes to sustainable banknotes, an early concern of a central bank are health and safety issues of the production of banknotes. A mile stone is the replacement of unfriendly wet strength agents containing formaldehyde for polyvinyl alcohol (PVOH) in the 1970s and 1980s. Around 2000, printing works reduced their chemical etching activities by digital plate making.
In the 1950s, interest was raised in durable banknotes, followed in the 1990s with interest in environmental issues, like Life Cycle Analysis (LCA). One of the topics in such a study is the yearly replacement rate of banknotes, which is commonly about one-third of the total number of banknotes in circulation (e.g. Federal Reserve Bank of New York, 2008). This yearly bulk is usually burned or used as landfill.

Sustainable banknote topic	**Year**	**By**	**Central bank/manufacturers**
Basic user requirements (figure 3.25)	> 1661	Early user requirements	Several central banks
	1974	Optimised for climate	Banque de la République d'Haïti
Durability	~ 1700s	First dimensional reductions	Several central banks
	1955	Varnish	De Nederlandsche Bank
	1988	Polymer substrate	Reserve Bank of Australia
Environmental aspects of production and circulation	1975	Flax replaced by cotton	De Nederlandsche Bank
	~ 1970s	Reduce energy consumption	Several manufacturers
	1999	Recovery system for wiping solution of intaglio printing	Oesterreichische Banknoten- und Sicherheitsdruckerei (OeNB)
	2000	LCA Cotton based banknote	Swiss National Bank
	2002	LCA Polymer based banknote	Note Printing Australia
Health and safety - production	1987	Replace solvent based varnish by water based	De Nederlandsche Bank
Corporate Social Responsibilities (CSR)	2007	Fair trade cotton	De Nederlandsche Bank
	2015	Public feedback of fair trade	De Nederlandsche Bank
	2009	Study colour-blind	De Nederlandsche Bank
	2011	Supply chain sustainability	De Nederlandsche Bank
	2013	Prevent bribery	Banknote Ethics Initiative

Figure 4.16
Impression of activities related to sustainable topics of banknote production and issuance.

Interest in sustainable banknotes increased around 2010, as a result of the introduction of Corporate Social Responsibilities (CSR), in Dutch "Maatschappelijk Verantwoord Ondernemen" (MVO). Aspects of a CSR policy are laid down in ISO 26000 (ISO, 2010b), functioning as a self-regulatory mechanism, whereby a business monitors and ensures its active compliance with the spirit of the law, ethical standards and national or international norms. In 2013, the topic of a CSR has been put on the agendas of central banks, focussing on the prevention of corruption and promoting compliance to anti-trust laws (Banknote Ethics Initiative, 2013). Four years later, 35 central banks and 10 accredited manufacturers expressed their support (Heinonen, 2017).

The topic of sustainable banknotes will become an important one, so is the opinion of the author. More than today people expect their payment instruments to be 'green'. As said, the replacement rate of cotton-based banknotes is high, and the water consumption also weighs heavily on the environment; a few litres of water is needed to produce the paper for just one banknote.
The following will elaborate in more detail on the topics introduced.

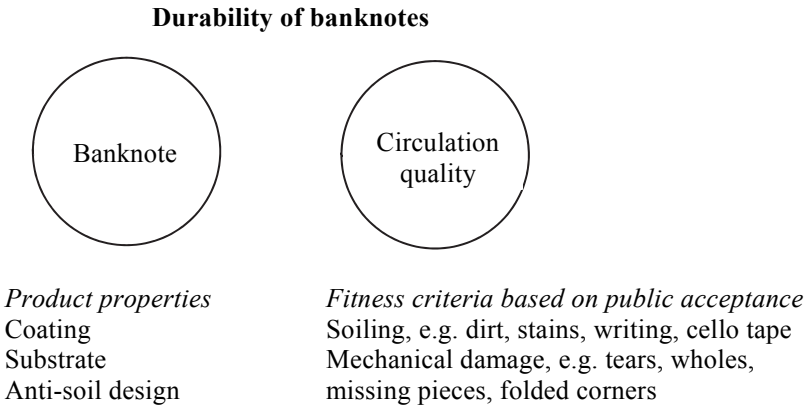


Figure 4.17
The durability of banknotes is divided in two domains, the product properties and the public acceptance of the quality of banknotes in circulation.

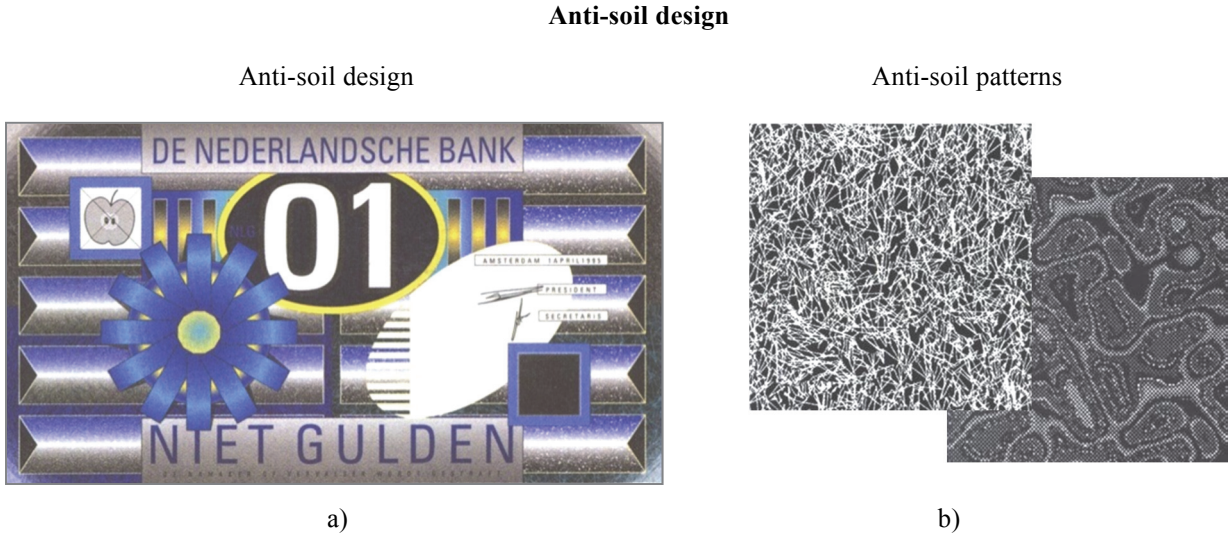


Figure 4.18
Concept for an anti-soil design for a banknote of 10 gulden (1995). Designer: Jaap Drupsteen.
a) Anti soil design.
b) Anti soiling banknote patterns, inspired by designs for carpets.

4.6.1 Durable banknotes

In the past, central banks did not recirculate banknotes and only issued new pieces, like in the United States, (McCabe, 2016). Once central banks started to recirculate incoming banknotes, their interest in longevity increased, mainly because of the replacement costs; for each destroyed banknote a new one has to be put into circulation. Obviously, central banks will therefore aim for durable banknotes.
When it comes to durable banknotes, two domains are relevant, the properties of the banknote and the public acceptance of the quality of circulating banknotes (figure 4.17). Banknotes can be optimised for durability by applying a coating (1), by introducing durable substrates (2) and by anti-soil design (3) or a combination of these strategies (De Heij, 2000; 2002b).
The public acceptance of the quality of banknotes in circulation has been studied (Van der Horst et al., 2011; Van der Horst et al., 2016). One of the main conclusions is that the public's judgement differs from the common opinion of central bankers, as will be reported in subsection 6.3.2 on neatness of banknotes. For example, the Dutch accept banknotes with a folded corner (dog ear) coming out of an ATM, while the European cashiers have an opposite opinion. As a result, about 30 % of the banknotes being sorted are unnecessarily destroyed.
The following focusses on the relevant product properties of a durable banknote, presented in their order of appearance: coating (topic 1), durable substrates (topic 2) and an anti-soil design (topic 3). Despite all efforts, banknotes cannot be protected against intentional damage, like drawing moustaches or applications of fire, including cigarettes used to burn out little holes on the place of a portrait's eyes in polymer banknotes.

1. Coating

Already in 1950, the Dutch central bank asked its printer Joh. Enschedé to develop a coating for banknotes which would increase their life (Servatius, 1955; 1956, reported in De Heij, 2002b). The first varnished banknotes were issued in 1955, coated with Ultramid Coating (UMC), a solvent based varnish. After the Dutch, the Swiss followed in 1971 with varnishing their banknotes.
Whether the varnish was effective had to be tested manually. With the introduction of banknote number reading in the 1970s *circulation trials* could be automated. Circulation trials are part of the User Feedback Model for Banknotes (figure 2.22). Treated and untreated banknotes are in a circulation trial compared with each other. Koeze and Van Gelder (1985) reported on a circulation trial in the Netherlands, comparing banknotes coated with DAR (Dirt and Abrasion Resistant, earlier named CAP) and uncoated banknotes. The result was that, using the coated variant, only 30% of the number of uncoated banknotes is needed to keep the circulation at the same quality. Based on the findings of this study all Dutch banknotes were varnished with DAR.
An extreme increase of life, 280 %, was reported for the NLG 100/Little Owl (Buitelaar, 1999, reported in De Heij, 2002). This increase is explained by the application of an iridescent ink layer on the front, printed in silkscreen, and introduced to prevent colour copying. This silk screen application covered the front for about 80 % and worked as a filler layer, smoothening the surface. On top of that the varnish contributed to this extension of the banknote's life.
Using a varnish on water basis for their banknotes, The Swiss reported that, a life increase of about 20 % compared with the previous varnish used; the life increase compared to unvarnished notes was not reported (study by Schumacher, reported in De Heij, 2002). Other central banks published as well on circulation trials including coated banknotes, like the European Central Bank, expecting an average lifetime extension of circulating banknotes of 25 % to 50 % (Meuer and Martin, 2011). Such life extension was not achieved by the Bank of England, reporting trials with an UV-coated varnish on five pound notes (Pearson, 2012). In this case the outcome was negative, the applied varnish did not contribute to longevity; the life of British banknotes was reduced by 9 %.
Central banks develop more interest in varnishing banknotes, like in the case of the euro. Respectively in 2013 and 2014, the 5 and 10 euro banknotes of the Europa Series received a varnish. In 2017, the ECB reported that "Varnishing has resulted in a substantial decrease of about 50 % in the note replacement volume, resulting for the €5 note in annual savings of about 500 million new banknotes" (European Centtral Bank, 2017a). Although a varnish proved to extend the life of euro banknotes, other euro denominations remain uncoated.

Soil is the main reason to take banknotes out of circulation and a coating may extend the banknote's life, so was and still is, the basic thought behind varnishing. It is remarkable that the reason why banknotes become dirty have hardly been investigated. Buitelaar (2008) investigated the colour of soil on banknotes. Balke (2011) demonstrated that sebum (finger fat) was the most influencing factor in explaining soiling banknotes.

2. Durable banknote substrate

A coating protects banknotes against contamination, but does not improve its *mechanical properties*, like tear resistance, folding endurance and tensile strength. Three properties are linearly proportional to the specifications of paper-based substrates, thickness (1), fibre length (2), and the number and structure of fibrils (3).

Six strategies have been identified to increase the mechanical properties of banknotes, which will be shortly introduced in historical order (De Heij, 2002b):
a) Banknote paper: natural fibre blends (since 1661),
b) Banknote paper: cotton mixed with artificial fibres (since 1974),
c) Synthetic substrates (since 1974/1988),
d) Banknote paper: pre-coated (since 1997),
e) Combined paper and synthetic substrates: multilayer structures (since 2007).
f) Combination of one or more of the techniques mentioned above.

a. Banknote paper: natural blends

Traditional banknote paper was a blend of cotton and natural fibres, like flax (e.g. US dollar), eucalyptus (e.g. Finish banknotes) or abaca (e.g. Philippines). Up to the 1970s Dutch banknote paper consisted of approximately 85 % cotton fibres and 15 % flax. In 1975, new tight legal regulations were announced regarding industrial pollution and flax in banknotes was judged to be no longer acceptable. Two circulation trials were by DNB, using two denominations, both 25 and 100 gulden, printed on *paper without flax* and *paper with flax* (Koeze, 1979; 1982c). The outcome was ambigious, paper without flax was more durable in the first trial, while in the second trial paper with flax lasted longer. However, DNB decided to abondone banknote paper with flax.
Another Dutch study considered the life of *long grain* and *short grain* paper. The outcome was that the paper's fibre direction was of no influence on the banknote's life (Koeze and Van Gelder, 1983).
It took several decades, up to the early 2000s, before the banknote industry offered new products that could prolong banknotes' longevity. Paper mills promoted strong banknote paper based on natural blends, carrying names like "Marathon" (by Crane).

b. Banknote paper: cotton mixed with artificial fibres

Aiming for higher mechanical properties paper manufacturers experimented with a blend of cotton and synthetic fibres. The Dutch paper mill Van Houtum & Palm (VHP) developed in the early 1970s a semi-synthetic paper, called "Paressyn", with a substantial percentage of plastic fibres. NLG 5 banknotes were printed on this paper and issued in 1974, the first in its kind. Although the paper showed higher mechanical properties, a circulation trial indicated a lower life for this type of note (the study remained unpublished). The explanation was that the plastic fibres were not fully embedded by the cotton fibres and sticked out of the paper. Because of static electricity these synthetic fibres attracted dirt more easily.

c. Synthetic substrates

The first 'plastic banknote' was issued in Haiti in 1974 and printed on "Tyvek", a synthetic fibre material. Ten years later, in 1984, the Bank of England experimented with one pound banknotes printed on "Bradvek", a variant of Tyvek. The banknotes were issued on the Isle of Man but were not successful, mainly because the ink came of the notes during circulation.

In 1988, the first successful introduction of banknotes printed on a synthetic substrate was realised in Australia (figure 5.25). This highly innovative banknote was printed on a polymer substrate, an oriented polypropylene (OPP), named "Guardian". The print on these banknotes also weared off and the notes were also very smooth. Therefore, later issues received a varnish, which reduced the ink wear off and also provided these banknotes a better grip, supporting the handling function of banknotes by people and by banknote machines. The polymer substrate proved to be adequate and since 1996 all banknotes in Australia are made of polymer. This innovation has been followed by more than 25 other central banks (Jeena, 2014).
Central banks which introduced polymer banknotes, like the Bank of Canada and the Bank of England, reported a longer life for banknotes printed on polymer instead of paper. The Bank of Canada reported that the polymer CAD 20, after being 46 months in circulation, lasts at least 3-5 times longer than its previous paper-based version (Malmberg et al., 2017). In 2013, the Bank of England concluded that polymer notes last at least 2.5 times longer than paper-based banknotes (Shonfield and Smith, 2013; Bank of England, 2016).
Introduction of synthetic banknotes will increase its life and may have a lower environmental impact. Futhermore, synthetic banknotes may lead to innovative authenticity features, like large transparent areas. Indeed, the introduction of polymer banknotes can be beneficial to the central bank and the banknote users, as concluded by Bouhdaoui et al. (2013).

d. Banknote paper: pre-coated

In the early 2000s, paper mills introduced *pre-coated* papers like "Diamone" (by ArjoWiggins), "Platinum" (by Portals) and "LongLife" (by Papierfabrik Louisenthal). A specific seizing covered the open surface of the paper, preventing soil penetration. After printing, these papers may also receive an after-*coating,* like a varnish.

e. Multilayer substrates (paper and synthetic combined)

Instead of a homogeneous synthetic substrate like a film, a multi-layer substrate can be composed. The first in this category is called "DuraNote" and consisted of 21 layers, offered in 1998 by a joint venture of Mobil Films and Agra Technologies. Another company, Domtar, offered in these years a composite of paper and plastic, a polyester film sandwiched between two layers of lightweight paper. However, it took up to 2007 before banknote paper mills presented *sandwich constructions* of both cotton and synthetic layers. The first was "Durasafe" (by Landquart), followed by "Hybrid" (by Papierfabrik Louisenthal). Both paper mills produced a substrate with three layers. Durasafe has a transparent layer in the centre and on both outsides a thin paper layer, a similar concept as Domtar. With a cotton centre, Hybrid is an inverse of Durasafe, with on the outsides a thin transparent film. The first banknote printed on Hybrid was issued by Swaziland in 2008, the SLZ 100 and 200 (Currency News, 2009) and the central bank of Kazakhstand was in 2015 the first to issue a banknote printed on Durasafe, the KZT 20,000.

f. Combination of one or more of techniques

Central banks may also combine different variations, such as a synthetic layer (topic c) with a coating (topic a). Another variant is a combination of pre-coating (topic d) and after-coating (topic a).
Banco the México reported on a circulation trial including four cotton based paper configurations, and it turned out that the combination of high durability paper and (an overall) varnish performed best (González Candela et al., 2014).

3. Anti-soil design

A relatively simple policy to improve the life of a banknote is *anti-soil design* (De Heij, 2007). The first measure in this field is to match banknote sizes to their storage devices like wallets (section 3.3); when banknotes are too large for a wallet, they will be damaged along the edges. A conceptual design for an anti-soil concept has been developed in 1995 together with banknote designer Jaap Drupsteen

(De Heij, 2007). The result is shown in figure 4.18, an example of the user function (UXF 5) guiding the design. A spin-off of this study is the proposal for a grey colour for the euro 5 (subsection 3.2.3).

4.6.2 Corporate Social Responsibilities

People expect that their banknotes are 'green', that the environmental impact of a banknote from the cradle-to-grave does not harm their society. An example has already been mentioned, the abolishment of flax in the paper substrate (subsection 4.6.1). Another example is the recovery of chemicals from the intaglio printing process, first realised in 1999 by the Austrian printing works.

A method to measure the environmental impact of a banknote is a *Lifecycle Analysis* or LCA. Comparing the outcome of different LCAs can only be done when the methods used are similar, including identical parameters. Standards related to environmental management are set by the ISO 14,000 family (ISO, 2006), aiming for minimising the negative effects on the environment (air, water, land). The basic principle behind these standards is an ongoing improvement on environmental impact.
The first LCA on banknotes was carried out in 1996 and reported by the Swiss National Bank (Wettstein and Lieb, 2000). The aim of this study was to gain insight in resource usage and emissions in producing and using of Swiss banknotes, like carbon-dioxide (CO_2) and ozone (O_3). Emissions were not only reported for the banknote's production, but also for its circulation, emissions created by motor vehicles and aircrafts transporting large volumes of banknotes.
An Australian LCA-study involved polymer and cotton-based banknotes and reported in favour of the polymer variant (Hardwick, 2002).
The ECB assessed the environmental impact of euro banknotes, which are cotton-based notes like the Swiss franc (European Central Bank, 2013d). The impact of euro banknotes is, over their complete lifecycle, equivalent to a European citizen driving a car one kilometre or leaving a 60 W light bulb switched on for half a day. The energy consumption of ATMs has the largest environmental impact.
A similar type of LCA study as carried out in Australia was prepared for the Bank of Canada (Marincovic et al., 2011). Its conclusion was that, compared to paper, polymer banknotes have 30 % less environmental impact, mainly because of the logistical efforts to transport banknotes from A to B.
When the Bank of England decided to change from cotton-based banknotes to polymer, they arrived at a similar conclusion as the Bank of Canada (Shonfield and Smith, 2013); polymer banknotes are found more environmentally friendly as they last longer, and, over time, are expected to be more cost effective than paper substrates.

LCA-studies provide insight into the environmental aspects of banknotes produced by different techniques. Such studies may also provide insights on the differences between the sustainability of different payment instruments, like coins and banknotes. The environmental impact of cash versus debit cards in the Netherlands has been studied (Roos Lindgreen et al., 2017). Their preliminary conclusion is that both payment systems show an equal environmental impact. In a second study, the impact of the use of debit card payments in the Netherlands was studied in more detail (Larcin et al., 2017). The entire lifecycle of debit card payments was taken into account: the production and the transport of a debit card, via the energy consumption of a pin terminal, to the processing of transactions in data centres. The conclusion of this study is that the total environmental impact of debit card transactions in the Netherlands is relatively modest compared to the impact of cash payments. Scenario analysis indicates that the environmental impact can be reduced by more than 40 %, by stimulating the use of renewable energy in payment terminals and datacentres, reducing the standby time of payment terminal, and by increasing the life of debit cards.

Corporate Social Responsibilities include ethical business practices. Within this spirit, DNB was in 2005 open to the suggestion to use "Fair Trade Cotton". In 2007, the first euro banknotes containing about 15 % sustainable cotton were issued (Currency News, 2008). Sustainable cotton can be produced by two concepts, as a product of a *fair-trade system* or as the result of *bio-dynamic produced* cotton.

A fair-trade system contributes to the improvement of the welfare of local cotton producers and the regions where they are located, by guaranteeing a fair price, prohibiting exploitative child labour and the use of unsafe pesticides. Requirements to the trade of sustainable cotton are left to non-profit organisations like Solidaridad, delivering a fair-trade certificate for approved productions. Bio-dynamic cotton aims for an environmental friendly production of cotton.
Sustainable cotton is offered to the market under labels like “Better Cotton” and such labels have their own criteria, which usually cover aspects of both a fair-trade system and bio-dynamic cotton.
DNB's initiative to include fair trade cotton in their paper for euro banknotes gained momentum in 2008 when a group of seven central banks of the Eurosystem ordered their banknotes together. This group is known as the JET-group, JET being an abbreviation of Joint European Tender (Van den Kommer and De Heij, 2008). The JET-group required paper mills to include 30 % of sustainably grown cotton, using natural fibre blends (De Nederlandsche Bank, 2012b). Sustainable cotton leads to slightly higher costs of banknote paper, which was accepted (section 6.10). In 2019, so is the intention, banknote paper should be based on 100 % sustainable grown cotton (Kuiper, 2016).

Another aspect of a sustainable banknote is the use of animal-derived components within the production. Synthetic banknotes tend to stick together, because of the effects of static electricity. A small amount of animal fat, tallow, added to the polymer will prevent this. When British citizens became aware that tallow was used in the polymer substrate of the new GBP 5 notes, they were dissatisfied (Graham, 2016). An alternative to tallow is palm oil. When the Bank of England suggested to use palm oil for the new GBP 20 polymer note, concerns were raised about deforestation and the environmental impact of palm oil plantations (Allen, 2017).

4.7 Linking to information technology (UXF 6)

Banknotes can be linked to Information Technology (IT). In the 1970s, the first connection was made between banknotes and DNB’s banknote sorting process, which was not yet fully automated, an example of a mechanical production process. When new, automated banknote sorting machines were introduced in the 1980s, a technical description was published in 1992, a novelty, as it unveiled the technical principals and performance of the detectors used, without informing on crucial details (De Heij and Van Gelder, 1992). This publication was followed by a publication on the development of banknote numbers and the information technology applied (De Heij and Van Gelder, 2006a; 2006b).
New links between banknotes and information technology have been proposed, like printing a QR-code on banknotes (De Heij, 2007), a link between a smartphone and a banknote (De Heij, 2007) and authentication with a barcode scanner by retailers (De Heij, 2010a). A far-reaching concept is a banknote design with just one banknote number, a concept for the high ATM-notes only (De Heij, 2012).
People seem to expect that central banks use ‘secret features’ to detect counterfeits, an expectation fuelled by the arrival of the Digital Revolution in the 1980s.

4.7.1 Number on banknote

In 1968, with the introduction of automatic number reading at DNB, two banknote numbers of the type “OCR-B” were printed on the gulden banknotes as shown in figure 4.19a. In 1973, the banknote sorting machines of DNB were ready to start with the actual process of automatic number reading of OCR-B numbers. Numbers read were, and still are, stored in a database and this file is compared with a list of valid numbers.
The follow up of OCR-B reading was barcode reading. Reading barcodes on consumer products started in 1973 when George Laurer (born 1925) developed the “Universal Product Code” (UPC). The UPC-A became the most common, using 12 numerical digits (figure 4.19b). The first product with a UPC was a packet of Wrigley's Gum and many other consumer products followed. In 1986, Canadian banknotes were the first to receive a barcode, a denomination code. This code was similar for each denomination and was detected by an electronic device (subsection 3.2.5).

In 1989, the two OCR-B numbers on Dutch banknotes were replaced by one barcode (figure 4.19c). In 1994 barcode numbers were also introduced on Lebanese banknotes. Although barcode numbering proved to have several advantages (De Heij and Van Gelder, 2006b), it is hardly applied. When the euro banknotes were introduced in 2002 their numbering was similar to the OCR-B banknote numbers, as introduced on the Dutch banknotes in 1968.

4.7.2 Chip in banknote

Perron et al. (2004) suggested to incorporate a chip in a banknote, illustrated by figure 4.19e. The chip could be used as a counterfeit deterrent and would have a read/write capability of 128-256 bits. Information stored on the chip could be overwritten about 10,000 times. The surface of the chip would be small, about 0.5 mm^2, and would be about 30 microns thick. In case of contactless reading an antenna would be needed of 15 mm x 15 mm. The reading distance would be in the range of 1-10 mm and the target price would be below 2 eurocent. In 2013, an ultrathin chip (~ 20 μm) has been embedded in a banknote type of paper (Swedberg, 2013). However, up to date, chips have not been applied in banknotes, probably because it conflicts with one of the appeals of banknotes, guaranteeing a person's privacy, as will be elaborated on in subsection 8.2.3; a chip in a banknote would be typically a case of technology push.
A chip-reader has access to the chip. Other reader information technologies may also connect a banknote with a reader, namely *printed electronics* and *Near Field Communication* (NFC). Banknotes may include a passive antenna which may receive wireless internet signals, like *Wireless Fidelity* (WIFI), symbolised by figure 4.12f or may emit a detectable signal as a reaction on a *Radio Frequency Identification* (RFID), symbolised by figure 4.12g.
An early example of banknotes equipped with an RFID circuit is the "Bijlmer euro" (De Heij, 2012). This sticker was used for tracking a part of the banknote's circulation in the region of the Bijlmer, a district of Amsterdam. The banknotes were regular euro banknotes with a yellow adhesive RFID-sticker and first appeared in 2010, aiming for increased awareness of citizens of the Bijlmer for their local economy.

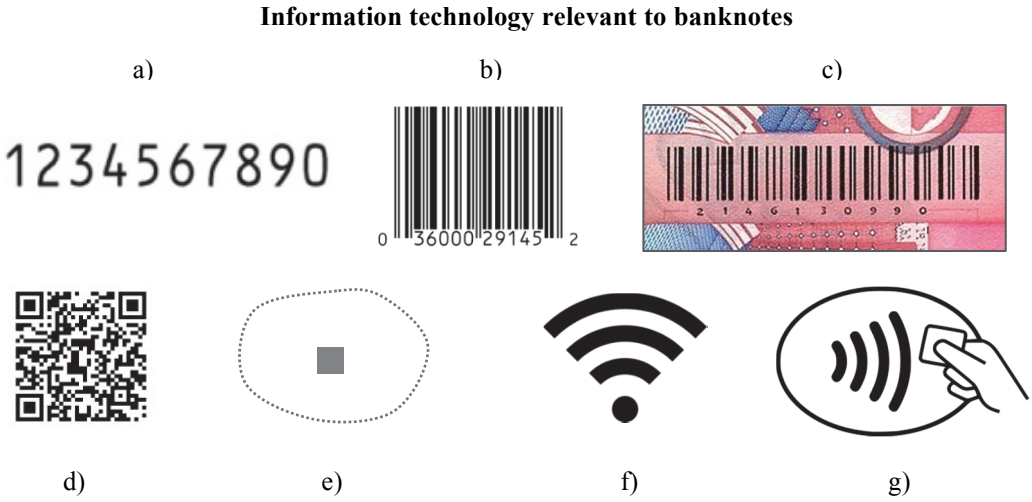


Figure 4.19
Impression of the development of Information Technology relevant to banknotes. Images: public domain (except figure 4.19c).
a) OCR-B numbering (Optical Character Reading, type B) applied for unique banknote numbering suitable for automatic reading in form of human readable figures.
b) Universal Product Code (UPC). The first UPC-codes appeared in 1973.
c) Unique banknote number suitable for automatic reading in form of a barcode. Shown is the barcode number on NLG 25/Robin, issued in 1989.
d) QR-code (2004). The first QR-code appeared on a banknote in 2014.
e) A chip in a banknote may hold fixed and variable information (2004). Not on scale.
g) Symbol for WIFI-zone (2009).
f) A symbol for Near Field Communication (NFC) (2013).

Barcode for retailer

Barcode reader and banknote

a)

Metameric

b)

Figure 4.20
Cashier feature with three functions: security check, denomination recognition and cash management developed in 2001 by Joh. Enschedé and DNB. Images: Joh. Enschedé.
a) Barcode on the banknote is readable with the laser light scanners used at supermarkets (660 nm).
b) Metameric barcode 'NoCopyCode', developed by Joh. Enschedé. A barcode with 'camouflage' based on metameric inks. Any code could be used, like e.g. EAN-13, EAN- 8.

Apps by DNB

App informing (2011)

a)

App checking (2015)

b)

Figure 4.21
The app uses the functions of a smartphone such as movement and touch. When the screen is touched on the place of the tactile area of the banknote, the phone will vibrate, simulating a feel sensation. The watermark will appear when the phone is held up to the light (look). Tilting the phone will display the holographic effects (tilt). Images: De Nederlandsche Bank NV.
a) App "EuroBiljet" launched by DNB in 2011 (developed by Visual Space, Amsterdam). Symbols 'feel-look-tilt' as developed by Bureau Mijksenaar are used.
b) App "Genuine or counterfeit" launched by DNB in 2015 (developed by Perceptech and Visual Space).

4.7.3 Banknotes linked to the internet

Banknotes can be linked to the internet in several ways. In 2004, people received a warning on their computer screen when they scanned a banknote at home. This warning system is part of the Counterfeit Deterrence System (CDS). Anyone trying to open a high-resolution image of a banknote in image editing software, such as Adobe Photoshop, is directed to the website www.rulesforuse.org, where the copyright rules of banknotes are explained in many languages.

The foregoing described various ways of linking a banknote to IT. It is conceivable that, in a next step, the entire banknote is replaced by IT applications.

The nucleus of variable data of a banknote is its number. Imagine that only this number would be provided to the user instead of a banknote. This idea could be the cradle of a solution for the inefficiency of high ATM-notes (subsection 3.2.1). To give an example, instead of a banknote the ATM may provide a ticket, a type of credit voucher with a code (De Heij, 2012). With this voucher, the public goes to the retailer and receives the desired cash, coins and small denominations as change. As a result, the refilling frequency of ATMs decreases.
Another suggestion is to print banknotes at home, like home-printed travel and theatre tickets. Such banknotes are designed by Van Enckevort (2008) and a barcode number received a prominent position (figure 4.8b). However, if the banknote number is key, the banknote number or code could also be displayed on the screen of a smartphone, eliminating the need for any piece of paper.

4.7.4 Authentication with a barcode scanner

The UPC-code has been introduced (subsection 4.7.1). The first UPC-scanner was installed at a supermarket in Ohio in 1974. After adding a digit, the "European Article Number" (EAN) was realised, later renamed in "International Article Number", retaining the abbreviation EAN. When an EAN- barcode would be printed on a banknote, the retailer may use its EAN-barcode scanner, which will read the code and informs the operator on its authenticity as illustrated in figure 4.20 (De Heij, 2010a).

4.7.5 Link banknote to smartphone

The following will continue with two topics related to linking a banknote to a smartphone. The first is a Quick Response code (QR-code), quite like the printing of the first barcodes representing the denomination on Canadian banknotes (topic 1). The second is the potential of apps (topic 2).

1. QR-codes

An automatic connection to a website is possible by using a QR-code (figure 4.19d). Scanned with a smartphone, the QR-code may link a smart phone to the website of a central bank (De Heij, 2007). The website may inform on the public authenticity features or any other type of information. Most likely, users will search for information on a specific banknote model and therefore each denomination should receive its own QR-code.
A dedicated website may provide information on how to verify the difference between genuine and circulating counterfeits. Banknote users may also appreciate other relevant information, like information on the area where the bogus notes are spread, and they may appreciate specific information on the performance of the public authenticity features. Obviously, the data provided should be up to date, a task for the central bank.
In 2014, the first banknote appeared with a QR-code, the NGN 100. After reading the code by a smartphone, a brief history of Nigeria appears on the smartphone's screen.

2. Apps

Suggestions to use a smartphone for an authenticity check on banknotes go back to 2007 (e.g. De Heij, 2007). One of the first technical concepts to realise an authenticity check with a smartphone has been published by Lohweg (2012).
At their simplest, smartphones can be used to record an image of codes, serial numbers or features. Such elements could be automatically validated in a central database. Details of banknotes may also be processed by image processing algorithms on resolution and geometry, or by capturing a spectral signature. It is even thinkable to detect special taggants.

In 2011, a connection has been realised between a smartphone and a banknote using the “EyeNote App”. With this app American blind could denominate US dollar banknotes (subsection 3.2.5). Other apps followed, especially apps on informing the public on authenticity features, like DNB's “Eurobiljet” (euro note), launched in 2011 (figure 4.21a). This app shows a virtual banknote and applies *augmented reality*. Holding the smartphone up to the light the watermark appears. In the same way, tilting the device allows for the exploration of the images within a holographic foil. Touching the virtual tactile areas, the smartphone vibrates. Other central banks followed with similar apps, like the Bank of England in 2015 and the Swiss National Bank in 2016.
Soon after the introduction of the Eurobiljet app, several users asked for an application which could scan and authenticate the banknote by itself. In 2014, a working prototype was presented by DNB, named “Genuine or Real”, shown in figure 4.21b (Van der Woude and Geusebroek, 2014), and launched in 2015 (Van der Woude, 2016).
New banknote series may anticipate on the arrival of smartphone detection. Using a smartphone as an additional human sense would expand the slogan *feel-look-tilt* to *feel-look-tilt-phone* or *feel-look-phone* (De Heij, 2012).
Taking an image of a banknote with a smartphone, the image may suffer from distortions. Positioning markers may assist the user and design solutions for such markers could be developed, like supporting positioning elements such as *corner markers,* a novel term.

4.8 Conclusions on User Experience Functions

The following User Experience Functions of a banknote have been described: experiencing identity (1), judging aesthetics (2), keeping confidence (3), connecting with main image (4), requiring sustainability (5) and expecting a link to Information Technology (6). The banknote designer must create design solutions for all six UXFs.
When a new banknote design is issued, people are mainly interested in the UXFs. However, UXFs are not necessary to make a payment and after some time people will rely on the UIFs. Design elements serving UXFs seem to be more multifaceted than design elements serving UIFs. The identified UXFs do not relate to machines processing banknotes, except for UXF 6, which requires a smartphone.

UXF 1 - Recognising identity

Experiencing identity (UXF 1) is expected to be the most decisive user function within this category, as people will not have much interest in banknotes which are not their own; a banknote should be recognised as representing ‘my country x or my area y’. In popular terms, a banknote is the ‘business card’ of the nation.
Identity has at least two facets: a nation identity and a design identity. The design identity relates to aesthetics (UXF 2); well-designed banknotes will contribute to the national identity.
An identity description should be ready before the development of a motto and a main theme may start. Positioning diagrams are helpful methodical tools to prepare such an identity description.
Texts are found to be the main design parameters of a nation’s identity.

UXF 2 - Judging aesthetics

Within one or two seconds people may have an opinion on the aesthetics of a banknote. Design variables leading the way to a beautiful banknote cannot be defined. Central banks are advised to invite one of the best designers, who can be a graphic designer or another type of designer, and does not have to be a banknote designer. Provide the selected designer a high design freedom.
A high design quality will contribute to the national identity (UXF 1) and, because of the halo-effect, will enhance confidence (UXF 3).
Aesthetics also plays a role in attracting attention. Seeing an attractive banknote for the first time, may help people creating a memory aid. At another moment in time, this mnemonic will help to retrieve specific information from people’s memory, for example to recall (some of) the public authenticity features. However, a clear conclusion about the relationship between aesthetics and knowledge on public features could not be reached.

UXF 3 - Retaining confidence

People do not want to worry about their banknotes; they just want to use them. Therefore, trust in banknotes is essential. Confidence in banknotes is dominated by confidence in the currency, as inflation reduces the value of the banknote. Inflation rates may lead to a currency reform which will affect banknote design, known as dropping zeros.
Confidence in the authority behind the currency can be enhanced by applying confidence features, such as the name of the central bank, the place and date of issuance, and a signature. When the technology of an authenticity feature becomes obsolete, a feature may lead a second life as confidence features, although it is recommended to abandon these features and to replace them by more secure (examples are a watermark and a gravure).
Confidence features represents a banknote's foot in the past, necessary to maintain confidence in fiat paper money, while modern authenticity features represent the contemporary foot, protecting the banknote from being mimicked.
Confidence is further encouraged by a consistent series design, a high quality of print and a clean circulation, underlining that the central bank is in control of its currency. The number of mimicked banknotes will influence confidence, although counterfeit rates may reach a level of 500 ppm, before the trustworthiness of banknotes will be undermined.
Central banks should reconsider their policy of informing the public on authenticity features. Instead of a continuous stream of general information, dedicated information could be provided. When the number of counterfeited banknotes passes a certain threshold, the public is informed about the denomination and on how to authenticate a genuine banknote.
Trust in banknotes has been stimulated by changes in the cash cycle, especially in the Western world. People take banknotes out of an ATM and bring these notes to the shops, where retailers increasingly verify banknotes with automatic devices. People no longer see the need for an authenticity self-check. In terms of the Model, the public shifts from checking authenticity (UIF 3) to keeping confidence (UXF 3). This change of attitude implies the development of confidence features rather than public authenticity features.

UXF 4 - Connecting with main image

A main image may evoke emotions and therefore it plays a role to connect people to a banknote model. Main images may serve the banknote's identity (UXF 1) and may also serve keeping confidence (UXF 3), for example by portraits of scientists, although in the Western world this is becoming an outdated policy. If applied, a main image should have a name and the image should be recognisable and understandable.
User Interface Functions may also benefit from a main image, especially when it supports instant value recognition (UIF 1). In that case, the main images within the series must be selected from different image categories.

UXF 5 - Expecting sustainability

Since 2010, there is an increased awareness in Corporate Social Responsibilities. Modern people expect that their banknotes are sustainable, that they are 'green', i.e. have a low ecological foot print. When banknotes harm nature or contribute to pollution they are experienced as being *un*sustainable, which may affect the identity of a banknote (UXF 1). People also expect that there is no child labour involved. Neither do they expect that their central bank places an order at banknote producers, which offer bribery money to acquire an order.
Central banks order durable banknotes to save replacement costs. As fewer banknotes will contribute to a sustainable banknote circulation, durable banknotes are connected to sustainable banknotes,. At this point, cost savings and durable banknotes come together.
The life of a banknote may be increased by anti-soil design, next to the application of long life substrates and coatings.

The clean note policy in the Netherlands goes further than the public demand; the Dutch public is willing to accept clipped corners and dirtier notes.
The acquisition of sustainable cotton contributes to sustainable banknotes.

UXF 6 - Linking to information technology

Information technology aims for mechanisation and automation, and banknotes are part of it. With the introduction of smartphones, people expect that they can verify the genuineness of a banknote (UIF 1). This new user requirement was fulfilled in 2014 when DNB launched the app "Genuine or counterfeit?"
A QR-code on a banknote may link a banknote directly to the website of a central bank.
Confidence in banknotes (UXF 3) is probably increased by visible links to information technology, which suggests putting the number on the front.
A link between a banknote and information technology is, in general, independent from other user functions, although 'information technology features' may influence the identity of a banknote (UXF 1), for example by the introduction of a QR-code.

For they look, but they don't really see.
Matthew 13:13

CHAPTER 5
USERS' PERCEPTION

5.1 Introduction

The user is put in front in a use-centered approach to banknote design, laid down in the Upid-Model (chapter 2). Therefore, it is relevant to have knowledge on *user behaviour* with banknotes. General knowledge on user behaviour with consumer products is the domain of *consumer behaviour,* blending elements from several knowledge domains, like psychology and sociology. The domain of *cognitive psychology* includes *human behaviour,* which, in turn includes *perception topics*. Perception is defined as the organisation, identification, and interpretation of sensory information in order to represent and understand the environment (Schacter, 2011).
Ongoing knowledge development on the human brain shows that the brain is much more complex then thought in the 1960s. Human brains have different networks for senses, emotions, actions, thinking and languages (Raymond, 2015). However, this chapter will provide some clues on the 'main trees within the forest'. These clues are partly speculative, which is inevitable, as knowledge on how the human brain processes visual information is still in developement.

In case of graphic design, people must perform a task in a *visual field property* or a *visual landscape*. To do their job properly, graphic designers need a *cognitive psychological theory on designing a visual field property* (Verhoef, 2007). Verhoef studied visual tasks, like finding a departing train on a departure scheme. People were observed in order to find out if they would notice two signs in the near surroundings of the departure scheme, respectively the sign that a vending machine is out of order and an instruction on how to insert a banknote.
What people are looking for in a visual landscape of a banknote depends of the user function they would like to operate, their user function mode (section 2.7). First, people must search the feature that supports the user function of their interest, like value recognition (UIF 1) or checking authenticity (UIF 3). Perception studies on banknotes will bring more user-friendly designs (Klein et al., 2004). Since then just a few studies have been published, like a study by Alter and Oppenheimer (2008) on the perception of portraits on one dollar banknotes (subsection 5.4.4). Although partial knowledge on the perception of banknotes is available, according to Verhoef, a cognitive psychological theory is absent on designing graphical products like a banknote.
One of the "Eight Golden Rules for Interface Design" is to reduce the short-term memory load (Shneiderman and Plaisant, 2010). Perception in *configural mode* and *feature mode* is introduced by Asch (1946). Kahneman (2011) described human behaviour by *System 1* and *System 2*, the first operating fast, the second slow.
How people take banknotes has been investigated (Lingnau et al., 2007), just as how people hold a banknote between their fingers (Wijntjes, 2009).

Recently, model building has started on the perception of genuine and mimicked banknotes, borrowing terminology and methodology from Signal Detection Theory, like a *false alarm* and a *miss* (e.g. Heeger, 2007). The hit-rate and the false-alarm rate can be converted into a measure called *d-prime* (d'). However, Eagleman (2017) argues:

> "The problem is that no one pays attention to banknotes. People who pass notes around in daily transactions don't typically pause to examine them carefully. The special ink, the watermark, the strip, the fibres, the hologram: these expensive security features are a wasted effort."

The problem statement of this chapter is borrowed from Eagleman (2017):
1) What details do people notice on banknotes, and why?
2) What features could be better designed to be brain-compatible?

This chapter continues with a review of knowledge gained on the perception of banknotes (section 5.2) and a review of measurement methods used for the perception of banknotes (section 5.3). The focus is on dedicated studies on perception of banknotes. The approach is to stick to the core area of expertise on banknotes and not to deduce theories from the domain of cognitive psychology.
Subsequently, several design aspects are reviewed which are relevant for the perception of banknotes (section 5.4). A novelty is the contribution of a model on people's attention for banknotes, presented in the 4M Model for the Perception of Banknotes (section 5.5). People's attitude towards new banknote designs is a separate topic (section 5.6), followed by the introduction of the Model for the New/Upgrade Ratio of a Banknote Design (section 5.7), before ending with concluding remarks (section 5.8).

5.2 Multi-sensory input

Every day, people make one or two payments with banknotes (subsection 1.3.1). A banknote is typically a product to be grasped, using routines, without paying much attention; perception of a banknote is based on prior knowledge. Prior knowledge about the banknote itself, but also about its surroundings. For instance, people tend to overlook complex reflections of a banknote as they are aware that light generally comes from above and therefore perceive a simplified version of the light interacting with the banknote. Based on experience with similar situations, the processing of visual information by the brain may ignore information or may fill in information gaps, relevant for an authenticity self-check.
Typical for a cash payment is that payers and payees are present at the same location, known as a *proximity payment* (Kosse, 2014). Therefore, people not only perceive a banknote, but also another person, either in his role of payer or payee. Proximity payments may also involve a machine, like an ATM (payer) or a banknote acceptor (payee).
In this section, the focus will be on the perception of the payee, when receiving a banknote from a payer. Taking a banknote, two stimuli are activated, vision and touch, a case of *multi-sensory input*.

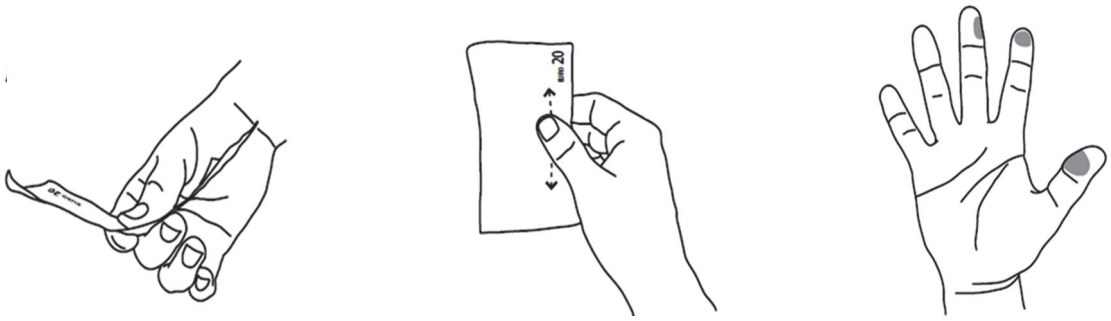
Stimuli from different senses may support each other, labelled *congruent*, or may create a conflict, being *incongruent*. This is a relevant phenomenon explained for banknotes in figure 5.1. This figure provides the hypothetical situation of four different banknote authenticity feature concepts for public use (A, B, C and D), experienced on their combined visual and haptic properties. When a stimulus is processed, the feature will be noticed, leading to a positive sensory effect (+). When the feature remains unnoticed, the sensory effect is neutral (o) and in case of an unusual stimulus of the feature, the sensory effect is negative (-). Concept A scores best, the visual effect and the haptic effect are congruent, they support each other.

MULTI-SENSORY INPUT				
Perception	**Feature concept**			
	A	B	C	D
Visual effect	+	o	+	-
Haptic effect	+	+	o	+
Multisensory effect	++	+	+	o

++ = high positive sensory effect o = neutral sensory effect
+ = positive sensory effect - = negative sensory effect

Figure 5.1
Four different, imaginary concepts for a banknote feature (A until D) scored on their sensory effects.
The best concept would be concept A, providing a score of ++ for multi-sensory information on respectively vision and touch. The least performing concept is D, representing a visual effect which eliminates the haptic effect.

Haptic banknote interaction

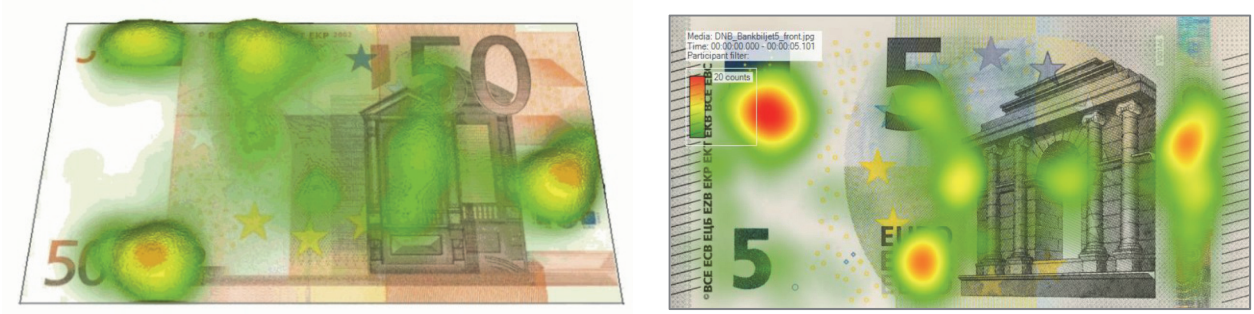


a) b) c)

Figure 5.2
Haptic banknote interaction.
a) Movement over the surface. Bending of the paper, fingers on two sides. Thumb on the front and index finger on reverse. The middle finger is sideways supporting the index finger.
b) Multiple contact areas. Thumb (and not index finger) is used to rub to and fro. It is assumed that typical movement ranges are about 20 mm.
c) Various banknote properties are perceived with three fingertips (thumb, index and middle finger).
Drawings by Dr. Maarten Wijntjes (Delft University of Technology) and De Heij.

Monitoring eye movement

Euro 50 (2002) Euro 5 (2013)



a) b)

Figure 5.3
Two examples of eye mark tracking.
a) Eye tracking registration of banknote of 50 euro (computer screen-averages). The image was made by reflection and offered on a screen and did not figure a watermark. The foil was a fixed image. There was no instruction given and the viewing time was 15 s (De Heij, 2010a).
b) Eye tracking registration of a banknote of 5 euro. The image was made by reflection and offered on a screen and did not figure a watermark. The foil was a fixed image. The front and reverse of the note was shown between 200 other images. To avoid sequential effects the images were offered randomly. There was no instruction given viewing and viewing time was 5 s (Neurensics, 2013).

In a study of Canadian banknotes (Klein et al., 2004) an accuracy of 92 % correct is reported for the detection of counterfeit and genuine notes, when inspection is done by "vision and touch" (VT). Respondents only using touch (T) scored 74 % correct and those only using vision (V) scored 87 %.

Multi-sensory input is seldom used to support banknote design. One example is known, which activates three human senses, known as the buzzing bee on the NLG 50/Sunflower shown in figure 1.1d (De Heij, 2006a). Scratching a nail over a gravure pattern produced the *sound* of a buzzing bee, one of the themes of this model.
There are no examples known that smell is used as a feature for a banknote. If smell would be added, this would lead to a multi-sensory input delivered by four senses. In general, people say that they like the smell of freshly printed banknotes, just as they like the smell of freshly mown grass (De Heij, 2012).

5.2.1 Visual effects

Humans have two eyes and the projection of the image is slightly different for each eye, because of a different location in space, a phenomenon called *binocular dispersion*. The brain uses this difference to create depth. Each eye splits the banknote into two pieces: one image on the side of the nose, the *nasal side*, and one image on the other side, the *temporal side*. The light that is reflected by the banknote reaches the human eyes. The lens within the eye projects the image on the retina upside down, inverted by 180 degrees. There are three cones, spectrally tuned to the short-, middle- and long-wave region of the spectrum, which are predominantly seen as blue, green and red, covering the spectral area between 400 nm to 700 nm. The center of the retina is the fovea and has the highest resolution. From both retinas, the banknote information makes a rather long journey passing several areas of the brain.

The first observation of a banknote is a visual stimulus; people see a banknote, before they can take it. The light that falls on a banknote, the illumination, is a complex situation. Various light sources will create the *light space*, the place where the banknote is used; the banknote interacts with the light space. For example, a banknote is brought from a dark wallet or cash drawer into the open department store, full of artificial light sources. Such a light space is completely different from the light space of the dark backseat of a taxi. Light sources vary from sunlight to artificial light and the light intensity may vary from bright to low. A banknote seen at a street market on a bright summer day, looks different at a Christmas market on a dark winter day.
When it comes to checking public authenticity features there are two situations, reflected light (R) and transmitted light (T) and the accompanying human action is respectively *look-at* and *look-through*. In case of reflection, there are two situations distinguished, *direct reflection* and *diffuse reflection*. Diffuse reflection is also known as *incident light*. A part of the light illuminating a banknote will be absorbed (A). Basic optical physics tell that R + A + T = 100 %.
Another aspect of the lightning conditions is whether the note is in a static situation or in motion.

Perceiving a banknote in motion in a light space is complex. During a cash transaction people cannot focus on the note, the banknote's colour will be their main visual stimulus. Receiving a payback note, people see a part of a rather blurred image and the first information sent by the payback note is its colour. Once the banknote comes to a standstill, colour will still be the main information, as the full perception of the note is often hindered by the payer's hand, which may partly cover the banknote at offer. A full perception may be further distracted by other banknotes and coins being part of the transaction. A new banknote design is usually observed by designers and decision makers in a *static* position; the advice given here is to assess a new banknote design also during a payment transaction, in motion.
Banknotes are usually viewed at a reading distance between 300 and 350 mm. Optimal perceivable design elements on such a reading distance should be, as introduced in subsection 3.2.2, about 30 mm x 15 mm (Ware, 2008). In general, human eyes are trained to go from left to right, rather than up and down.

5.2.2 Haptic effects

Touching products is less studied than the visual perception of products.
When people take a banknote, their fingers may slide over the surface. As movement is involved, they will experience a *haptic stimulus,* a sensation caused by changes in the skin of the fingers used. In the case of banknotes this stimulus is caused by the two sides of the object, the front and the back, making this stimulus even more complex to understand.
People cannot use banknotes without taking them in their hands. People will see and feel one side, while the other side can only be perceived by touch. Usually, heat plays a role too, but not in case of banknotes. Excluding heat, skin stretch is caused in three ways, by skin indentation (e.g. a pin), by deformation (e.g. softness) or by friction changes of the surface material (e.g. from slippery to sticky). All three may play a role when people take a banknote. However, taking a banknote will mainly be a matter of skin indentation, which is registered by *mechanoreceptors*. These receptors are subdivided in receptors being sensitive to slow or rapid stimulation. Mechanoreceptors react by a linear function of the depth of skin indentation, being sensitive within more than six orders of magnitude in force, from some Milli Newton (mN) to hundreds of Newton (N).
The haptic stimuli provided by taking a banknote has been object of study (Wijntjes, 2009). Usually a banknote is hold between two fingers, the index finger on the reverse and the thumb on the front (figure 5.2a). The middle finger is sideways assisting the index finger, giving counter-pressure to the thumb. The top index finger is not actively used. It is the thumb and not the index finger that is used to rub to and fro (figure 5.2b). These analyses bring an important insight. As the most sensitive finger, the index finger, is usually on the reverse of the note, it will be more effective to bring tactile features to the back (instead of the traditional front).

The combined effect of vision and touch is echoed in the motto “Feel Look Tilt” which was developed for the first issue of the euro banknotes in 2002 (subsection 3.5.2). Later, in 2004 new US dollar banknotes were supported by a similar type of slogan: “Maintain an American Look and Feel”. In these mottos feel covers the combined haptic stimulus of the substrate and the raised print. Other design elements may also contribute to the haptic experience, like the smoothness of a foil feature. Banknotes are said to be a 2D-product, but they do have a z-axis component, the ink layer of the gravure, which is in general up to about 60 μm high. People may feel this relief on new banknotes, but it is less perceivable on used banknotes. A study by TNO/TPD in 1983 reported that the ink relief on used banknotes is lower than on new banknotes, caused by the relaxation of the paper fibres, while the printed ink layer maintains its height (study reported in De Heij, 2009). It is not only the relaxation of the paper fibres reducing the haptic perception, also all sorts of wear and tear, such as wrinkles, will create a ‘tactile noise level’. Together, all these effects provide a limp feeling to a paper-based banknote which has been in circulation for some time, a feeling quite different from the perception of a crispy new banknote. Foil features may even completely wear of, due to abrasion or solvents (De Heij, 2010a). Such degradation effects create ambiguous conditions for the perception of a feel feature. However, several studies report that people can discriminate between the haptic effects of an original and a counterfeited banknote. Because ‘it felt different’, they are triggered to do an *authenticity self-check* on a just received banknote.

O’Byrne (1996) reported that Irish super market checkout staff (70 %) were alerted by the feel of the note (study reported in De Heij, 2009). The same figure was reported for euro banknotes (De Heij, 2010a): “the most common security feature noticed by cashiers is tactility (70 %)”. The importance of feel is also confirmed by a study done in the USA: “just received banknotes are actively checked on a suspicious feeling by 25 % of the cash handlers, against 6 % of the general public” (De Heij et al., 2003). A study discriminating between ‘feel of the paper’ and the ‘feel of the raised ink’ reported that the feel of the paper is the most frequently verified authenticity feature, respectively by 65 % of the public and 56 % of the retailers, while raised print is mentioned by 35 % of the public and 30 % of the retailers (Pérez et al., 2014). In 2013, almost half of the Dutch (about 40 %) said that they discovered a counterfeit because of its different appearance, like a different feel or structure (Visser and Dijkers, 2013). In this same study, respondents tell that they are triggered by the feel of the banknote to start an authenticity self-check.

An Austrian study reported that the preferred action of 'feel-look-tilt' for professional cash handlers is feel (66.8 %), followed by look (49.6 %) and tilt (30.0 %) (Taborsky, 2013).

Summarising, the reported studies make it plausible that feel is people's first trigger to recognise a counterfeit. Taking a banknote, people perceive the note in motion, which hinders a focussed visual attention. Furthermore, the short-term visual memory is occupied with denominating and handling of the change. Meanwhile, the capacity of the tactile working memory allows for the detection of a deviating tactility.

5.3 Measuring methods for the perception of banknotes

Perception studies of banknotes may be carried out in various ways, with the help of equipment or by means of interviews, as indicated in Moggridge's diagram (figure 2.19). Monitoring eye movements will be reported first (subsection 5.3.1), followed by a method for testing isolated features (subsection 5.3.2) and measuring emotions (subsection 5.3.3).

5.3.1 Monitoring eye movement

Monitoring of eye movements is a regularly applied method. In 2005, the Bank of England experimented with *eye ball tracking*. This research was video-based and was designed to collect eye positioning data. Since then, the techniques have been improved, and at conferences central banks are able to present eye travel paths within their banknotes (e.g. Banco de Mexico, European Central Bank, Bank of England).

When people look at a banknote, the fixation of the human eye can be registered, known as *eye ball tracking* or *eye marking*. Eye movements are registered by an infrared tracking device, typically with a frequency of 50 times per second. Going through a visual landscape the human eye automatically fixates on high contrast edges and areas of high resolution.
Searching for a specific feature the eyes move from fixation to fixation. This fixation is the *dwell period* and is typically between 0.2 s and 0.3 s and may take up to 1 s. During the dwell period, the eyes may make a very rapid movement over the banknote's surface, the *saccade*, which takes between 0.02 s and 0.1 s. During this short period visual stimuli are not processed and people will not consciously see something.

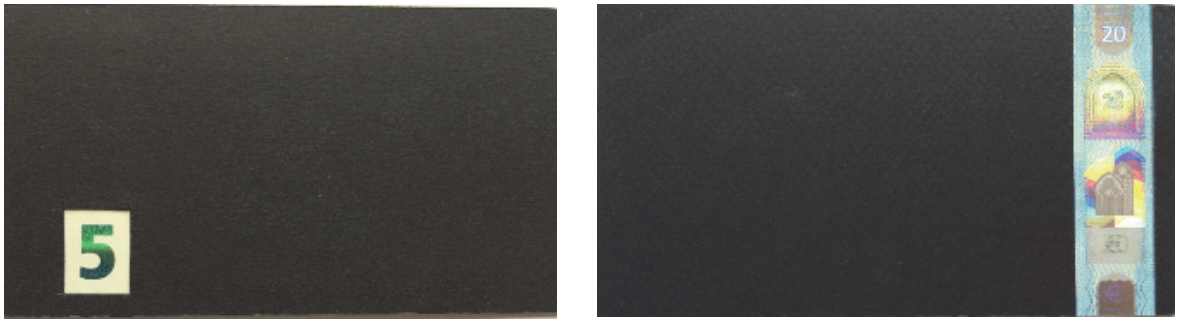
Central banks would like to know whether the public will see a *Region of Interest* (RoI), a specific feature, like a numeral or an authenticity feature. Whether the human eye has visited a RoI can be recorded in two ways. Both methods provide an answer to the basic question behind eye marking, does the human eye cross the relevant design elements of a banknote or is the eye distracted by other parts? The first method aims for the fixation on specific locations. A *scan path* presents the design elements that the eyes have visited once or more frequently. The second method records the dwell period, telling how long the eye rested on a RoI, usually presented as a *heath map*. Heath maps of a euro 50 (2002) and a euro 5 (2013) are respectively provided in figure 5.3a and 5.3b. These two heath maps confirm that the eyes travel to high contrast areas and surpasses lower resolution regions. However, interpretation of the results is ambiguous, as subjects may also register design elements in their periphery, just out of their focus. Furthermore, results depend on the instructions given to the observer.
Analysing these two images leads to the conclusion that text elements within the euro attract the eye, especially the words EURO and EYPΩ. The silver foil patch, the flag and the signature are also of interest to the observer. Only for a moment the human eye rests at the centre of the arches, which is probably triggered by its high contrast.

Summarising, sharp transitions in density grasp people's attention. Blurred areas receive no interest.

FOUR TEST SITUATIONS FOR AN AUTHENTICATION SELF-CHECK		
	Features offered	
	In complete banknote (fantasy or genuine)	Isolated
Instructed	A	B
Intuitive	C	D

Figure 5.4
Four test situations for an authentication self-check.

Isolated authenticity features



a) b)

Figure 5.5
Examples of 'banknote cards' showing isolated authenticity features.
a) Emerald number in EUR 5 of Europa Series (issued in 2013).
b) Foil feature in EUR 20 of Europa Series (issued in 2015).

FEATURE - RESPONSE MATRIX GENUINE OR COUNTERFEIT			
		Response	
		+ Genuine	- Counterfeit
Authenticity feature or complete banknote	+ Genuine	+ + Hit	+ - False alarm
	- Counterfeit	- + Miss	- - Correct rejection

Figure 5.6
The feature-response matrix for genuine and counterfeited authenticity features or the complete banknote.
Hit = genuine perceived as genuine.
Miss = counterfeit perceived as genuine.
False alarm = genuine perceived as counterfeit.
Correct rejection = counterfeit perceived as counterfeit.

5.3.2 Testing isolated features

Features in a banknote can be tested on their effectiveness in two ways, within a complete banknote or as an isolated feature. Furthermore, respondents may receive an instruction on how to verify the feature, or they may not receive any instruction and have to rely on their intuition. These four situations are presented in figure 5.4.Figure 5.5 provides two examples of isolated features in euro banknotes. An isolated feature has the advantage that people aren't distracted by any other design elements, either in genuine or in fantasy banknotes.
The first to report on masked features in banknotes is the Bank of Canada (Firth and Balodis, 2011), presenting the results of perception tests carried out on isolated authenticity features within Canadian banknotes, which had to be judged intuitively by different respondents, an example of category D. In 2017, a similar type of test with isolated features of euro banknotes was done in the Netherlands (Van der Horst et al., 2017). The ability of people to detect the counterfeits in this study has been reported with the help of the *feature-response matrix* as displayed in figure 5.6, identifying four possible situations. The matrix and the terms are borrowed from the Signal Detection Theory (e.g. Heeger, 2007). The *hit-rate* (h) and the *miss rate* (m) can be converted into a sensitivity index *d'* or *d-prime* and is explained with the aid of the following example. A set of 10 banknotes contains 7 real and 3 counterfeits. The banknotes are randomly offered to the first respondent, which divides the set in 8 real and 2 counterfeits, scoring $h_1 = 7$ and $m_1 = 1$. Note that $h_1 + m_1 \neq 10$, because misses and false alarms are not part of the calculation of d-prime. The second respondent divides the set correctly in 7 real and 3 counterfeits, scoring $h_2 = 7$ and $m_2 = 0$. Doing so for n respondents, the mean of h_1 up to h_n is calculated (μ_h) which is for example $\mu_h = 7.3$. Subsequently, the standard deviation σ_h is calculated, which is for example $\sigma_h = 0.8$. Similarly, μ_m and σ_m are calculated, which turn out to be for example $\mu_m = 1.6$ and $\sigma_m = 0.9$.
After these preparations, the Z-score of the hitrates of the first respondent, $Z(h_1)$, can be calculated as follows:

$$Z(h_1) = \frac{h_1 - \mu_h}{\sigma_h}$$

The Z-score of the hitrates for the first respondent is for example $Z(h_1) = 0.75$.
In the same calculation the Z-score of the miss rate of the first respondent $Z(m_1)$ is:

$$Z(m_1) = \frac{m_1 - \mu_m}{\sigma_m}$$

For the first respondent, this Z-score turned out to be for example $Z(fm) = -0.55$.
Subsequently *d'* for the first respondent is calculated as follows:

$$d'_1 = Z(h_1) - Z(m_1)$$

In the examples used, d-prime for the first respondent would be 0.10. The exercise is repeated for each of the n respondents and the average d-prime is calculated.
In case of banknotes, d-prime is the *authenticity sensitivity,* people's ability to discriminate faked eatures from genuine ones. An overview of several authenticity sensitivities for banknotes, d-prime values, is presented in figure 5.7. When people are not able to make a distinction between genuine and counterfeit other than by gambling, the features sensitivity represents 'chance performance' ($d' = 0$). When all originals are detected, and no counterfeits are marked as genuine, the feature would be perfect ($d'=4$). A negative value means that participants think that the counterfeit is more genuine then the genuine ones.
The authenticity sensitivity is becoming an accepted method to classify authenticity features, recently several studies report on their d-prime valuess, as reported in figure 6.21.

5.3.3 Emotions evoked by banknote design

Banknotes are a utility product, to be used by all citizens. Therefore, central banks may aim for a 'middle of the road design'. Flat designs will not offend people, but neither will they please people. The drawback of such an approach is that people shrug their shoulders and are not feeling a bond, as seems to be the case for the euro banknotes in the Netherlands (Fong, 2011). The second series of euro banknotes did not bring a change, as it remains to criticasters a banknote without a face (Stürmer, 2015).
Basic emotions are classified by Ekman (1972) in positive and negative emotions. A method to measure emotions evoked by a product is developed by Desmet (2002), following Ekman's basic emotion scheme. Respondents express their emotions by a specific questionnaire, which included a navigator, a drawn character producing motions and sounds. Desmet's method has been used to measure the following five positive emotions (De Heij, 2006a): satisfaction (1), pleasant surprise (2), fascination (3), desire (4) and amusement (5). The corresponding five negative emotions are: dissatisfaction (1), unpleasant surprise (2), boredom (3), disgust (4) and contempt (5). The outcome was that euro banknotes do neither evoke positive emotions, nor negative ones (subsection 6.7.2).
Some examples of banknote designs triggering emotions are provided in figure 5.8. A banknote depicting a unicorn is an example of a pleasant surprise, referring to fairy tales (figure 5.8a). An embryo on the proposal for a new Swiss banknote design, already introduced in section 4.5, turned out to be an example of an unpleasant surprise (figure 5.8b). Application of the emotion desire is another appropriate design theme, like the image of Maria Callas on a fantasy banknote, expressing melancholy (figure 5.8c). Melancholy relates to 'longing to the past' and the contemporary design sets the other foot into the future. An example of addressing fascination is provided in figure 5.8d. Is the lady singing or screaming?
In 2016, emotions evoked by cash versus electronic payments were investigated in 2016 (Van der Cruijssen and Van der Horst, 2016). In this study, the variable "emotion" is defined by the following six different positive emotions: pleasant (1), safe (2), familiar (3), modern (4), valuable (5) and simple (6). The outcome was that paying electronically feels more modern than paying cash, but also more pleasant, safer, more familiar, more valuable and simpler. The largest difference between cash and electronic payments is for the feeling "modern".

5.4 Design aspects relevant to the perception of banknotes

A well-known perception phenomenon in graphic design is a *visual string* (e.g. Ware, 2008). People will read a denomination numeral 50 as a one *chunk*, instead of perceiving a separate 5 and a separate 0; people tend to group design elements together.
Furthermore, memorising banknotes is influenced by the *serial position effect*, as people tend to recall the first (*primacy effect*) and last items in a range of topics best (*regency effect*), a phenomenon first described in 1885 by Hermann Ebbinghaus (1850-1908).
This section continues with observations on the perception of banknotes which are relevant to the banknote designer. First the heuristic and rule-based quality will be introduced (subsection 5.4.1), followed by prototypical design elements (subsection 5.4.2) and inner and outer images (subsection 5.4.3). Subsequently, the perception of portraits and other images is reviewed (subsection 5.4.4), before ending with the perception of public authenticity features (subsection 5.4.5).

5.4.1 Heuristic quality and rule-based quality

For a better understanding of the perception of banknotes, *heuristic judgement* as introduced by Kahneman (2011) is a relevant term. Heuristic refers to discover, knowledge gained by incidence. The heuristic judgement of a banknote is the expected quality of a genuine banknote, here referred to as the *heuristic quality*. The opposite term of heuristic quality is *rule-based quality* and refers to knowledge on the individual features.

AUTHENTICITY SENSITIVITY VALUES	
Authenticity sensitivity (d-prime or *d'*)	**Remarks**
Negative	Counterfeit is perceived as being more genuine then the genuine ones.
0	Chance performance.
1	Many counterfeits are classified as genuine.
1.25	Most counterfeits are classified as counterfeit.
2.5	About 90 % of the counterfeits are correctly detected; circa 10 % of the genuine notes are mistakenly judged as a counterfeit.
4	All originals are detected and no counterfeits are marked as genuine.

Figure 5.7
Overview of d-prime values and the corresponding authenticity sensitivity.

Banknotes triggering emotions

Pleasant surprise
Unicorn (1996)

Unpleasant surprise
Embryo (2005)

Melancholy
Maria Callas (2007)

Fascination
Singing lady (2009)

a) b) c) d)

Figure 5.8
Examples of banknote designs triggering emotions.
a) Proposal of Robert Oxenaar for a banknote of 100 euro, 1996 (European Central Bank, 2003).
b) Proposal for a new Swiss banknote CHF 100/Embryo, 2005. Designer Manuel Krebs.
c) Fantasy banknote by Roger Pfund, featuring a portrait of Maria Callas (1923-1977). Design was presented at Currency Conference, 2007.
d) Singing lady. Design prepared for the Dollar ReDe$ign Project, 2009. Design by University of Minnesota.

Rapid drawings for a new euro banknote

a) b)

Figure 5.9
Two banknote designs for a new euro banknote made by 12-year-old children in 2008. Designs were made within 15 minutes.
a) Design of a banknote of 5 euro.
b) Design of a banknote of 20 euro.

Which banknotes are hidden behind the grid?

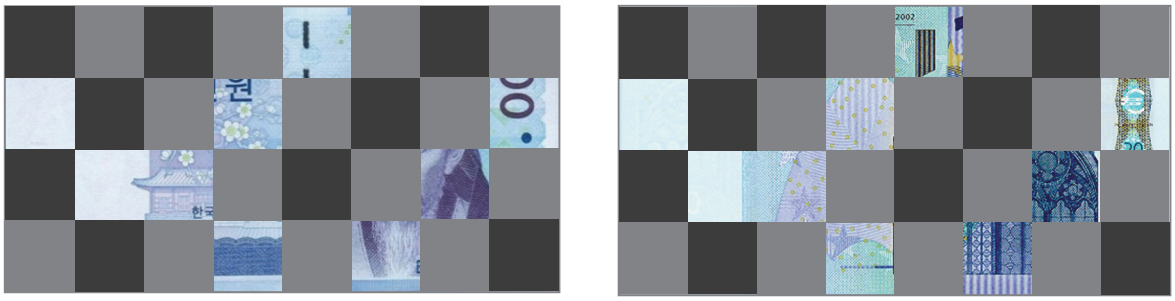


Figure 5.10
Get the picture! Prototypical design elements of these two banknotes are covered. How many tiles should be removed before the image becomes clear? See figure 5.11 for the answers. Images: De Heij.

KRW 1,000 (2007) EUR 20 (2002)

a) b)

Figure 5.11
Get the picture!
a) South Korean won 1,000, issued in 2007. The portrait is a Toegye, a Confucian scholar.
b) Euro 20, issued in 2002.

Banknotes have the highest printing quality, so is the public's belief. This fuels people's heuristic judgement and may put them on the wrong foot. When a reproduced banknote shows more saturated colours, people may perceive a mimicked banknote as real. A similar misjudgement can be made when a reproduced banknote provides a sharper impression or a glossier foil. A novel glossy colour changing feature on the euro 5, the first banknote of an upgraded series of euro banknotes, was judged as "being too glossy and shiny", which comes across as counterfeit (Van der Horst et al., 2017). Another example of a heuristic quality is that people expect banknotes to be in a good shape, they would rather not accept damaged banknotes.

5.4.2 Prototypical design elements

People will identify a piece of paper as a banknote because of *prototypical design elements*, like size, signature and banknote numbers. Even when people have never seen a specific banknote before, for example when they are abroad, they are able to identify the unknown piece of paper as a banknote. US dollar notes have a similar colour and size and to foreigners they may look quite similar. However, Americans are not confused, because they have a *preconception* of their notes and they only remember the details that are useful to them (Norman, 2013). This preconception is stored in a visual area of the long-term memory and is called the *believed original* or the *category prototype* (Hoyer and Macinnis, 2008). When people perceive a bicycle without a front wheel, they will notice this immediately. But, when a banknote misses one of its authenticity features, this remains usually unnoticed. The category prototype is build up from *prototypical design elements*. Such elements can be unveiled by asking people to make a rapid drawing of a banknote. The drawings shown in figure 5.9 are made by 12-year old children, within a few minutes they created a design for a new euro banknote (De Heij, 2010a). These designs typically included a large numeral, rectangular areas, the euro currency symbol (€), the EU flag and a silver coloured stripe. Although Italian school children received more time for their entry to a design contest for euro banknotes, similar effects are observed (Banca d'Italia, 2014). Prototypical design elements of a banknote can also be unveiled by covering a banknote with tiles, as done in figure 5.10. Once the prototypical design elements are not yet unveiled, both banknotes show similar colours. When the prototypical design elements are unveiled, it becomes clear that the two models are completely different (figure 5.11).

5.4.3 Inner images and outer images

People use banknotes every day, year after year. As a result, people will have a strong *inner image* of a banknote, which may differ from the real, *outer image* of the same banknote.
The visual sense is not like a camera that takes in the complete scene. Instead, humans only see the details that their brains go out to seek (Eagleman, 2017). When people pay attention, they will register more details of a scene and they will ask themselves what it is that they are looking at. In the case of banknotes, people think that they already know the banknote in their hands. Therefore, they don't scrutinise the details and only perceive a glance of the banknote. This glimpse of an outer image is for humans enough to perceive an image of the banknote, which will be compared to an inner image stored in their long-term memory. Figure 5.12 presents fabricated examples of outer and inner images of two different euro 10 banknote models, following the example of a fabricated inner image of a dog (Ware, 2008; De Heij, 2010a; 2015b). The two inner images of the euro 10 (figure 5.12c and d) show fewer differences than their two outer images (figure 5.12a and b).
When people are asked to imagine a banknote, they will retrieve an inner image of a banknote from a visual area of the long-term memory. An outer image is how people see a banknote in daily life, before the image is processed by the brains. An inner image can be recalled in two ways:

1) By looking at a banknote (external stimulation),
2) By memory only (internal stimulation).

Inner images will show fewer details than outer images and will also include associations. Inner images will change over time, they are not static, and should therefore not be compared with fixed repositories like a photo. People not only use banknotes of their own currency, occasionally they will also use foreign banknotes, for example when they are on holidays. Furthermore, older people may recall older banknote models, which are no longer circulating, but may still be part of their visual memory. These variations of banknote designs makes that the inner images that people will have of their local banknotes will not be the same.

5.4.4 Perception of portraits and other main images

From all design elements, the main image occupies most space on modern banknotes. In the early years, the size of a portrait covered about 10 % of the surface, while the area occupied by a portrait in modern banknotes may cover up to 50 %. Other type of main images, like a building, may also claim almost half of the front's surface. What are the arguments to allocate so much space to a main image? How should the main image be valuated? This subsection provides an answer to both questions.

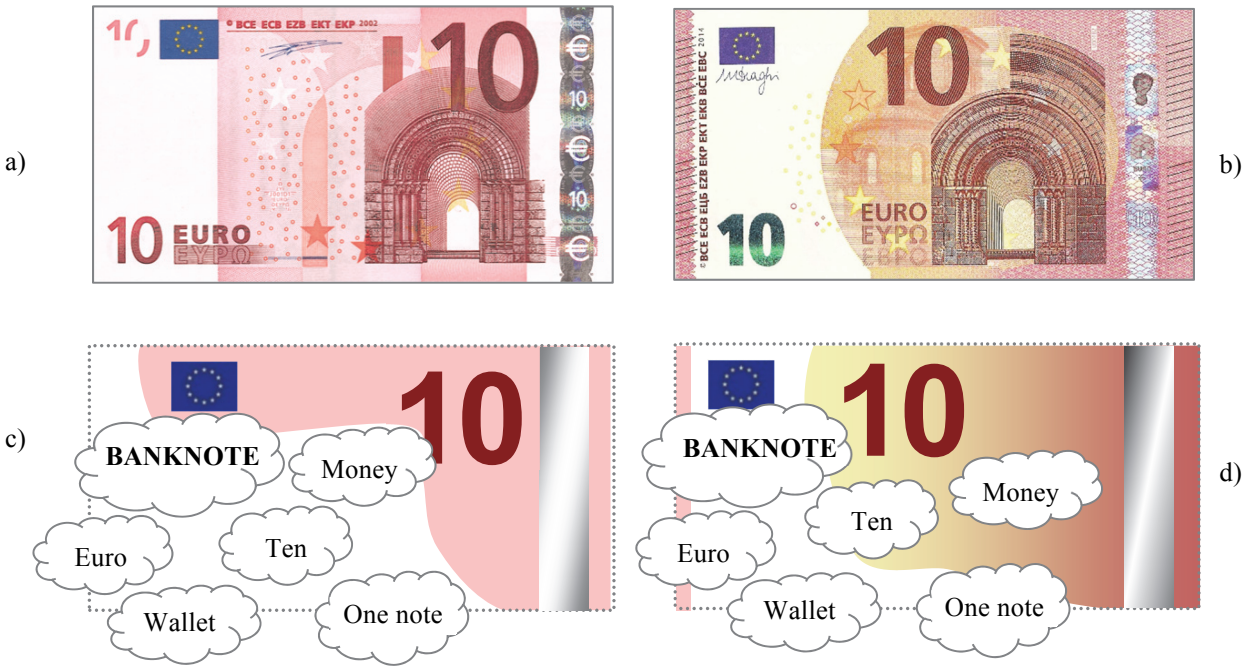
Early visual analysis by the brain is grounded on two basic principles: *contrast frequency filtering* and *colour filtering* (figure 5.13). Frequency filtered images of banknotes provide an idea of how images of banknotes might be processed by the human brain (figure 5.13a). Such images confirm that the brain is interested in high contrast changes, as evidenced by heath maps (subsection 5.3.1); an image becomes dominant by its silhouette. Therefore, 2D-type of images with a recognisable outline will probably be recognised earlier than 3D-type of images with blurred edges. Second, basic colour information will be provided by colour filtering, suppressing other colours than the dominant colour (figure 5.13b).

Before images on banknotes were examined, pictures as used on coins were subject of perception studies. In the 1970s, the images on the well-known coin of one dollar cent became object of study, displaying on one side the face of Abraham Lincoln (1809-1865) and some texts. The question to be answered was, how completely and how accurately do people remember the visual details (Nickerson and Adam, 1979). Respondents showed a poor recollection of the correct design features, like the orientation of Lincoln's face and the position of texts. A similar experiment was done with a British coin, a piece of 10 pence, and confirmed the earlier findings; only 15 % of the respondents could identify the correct piece out of 12 variants (Morris, 1988). Norman (2013) concluded that visual details of familiar objects, like coins and banknotes, are only available from memory to the extent that they are useful in a person's everyday life; people don't need to remember all the details to distinguish one denomination from another.

Portraits on banknotes were already advised in 1837 as a measure to prevent counterfeiting of Austrian banknotes (Kranister, 1989). In 1854, portraits were also advised for British banknotes (Hewit and Keyworth, 1987). The forger's reproduction process would cause distortions in the human face. A portrait of George Washington (1732-1799) features US dollar notes since 1861. Since 1929, this portrait is displayed on the well-known one dollar bills, which are still in use. This note became object of a study in a similar experiment as above described for coins, delivering similar results; people are not confident which of the two notes shown in figure 5.14 is correct (Alter and Oppenheimer, 2008). Is the portrait facing to the left or to the right?
Another topic is the recognition and recall of portraits displayed on banknotes. People seem to have a poor recollection of who is portrayed on a banknote, as will be reported in subsection 6.2.1.

Inner and outer images

Outer images euro10

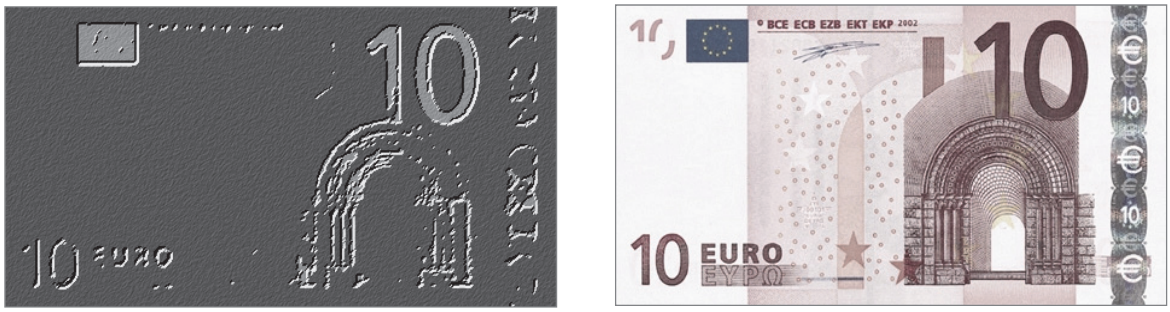


Inner images euro10

Figure 5.12
Illustration of outer and inner images of banknotes.
a) Original banknote of 10 euro (issued in 2002).
b) Upgraded banknote of 10 euro (issued in 2014).
c) A fabricated inner image of a banknote of 10 euro (issued in 2002).
d) A fabricated inner image of a banknote of 10 euro (issued in 2014).

Early image processing by the brain

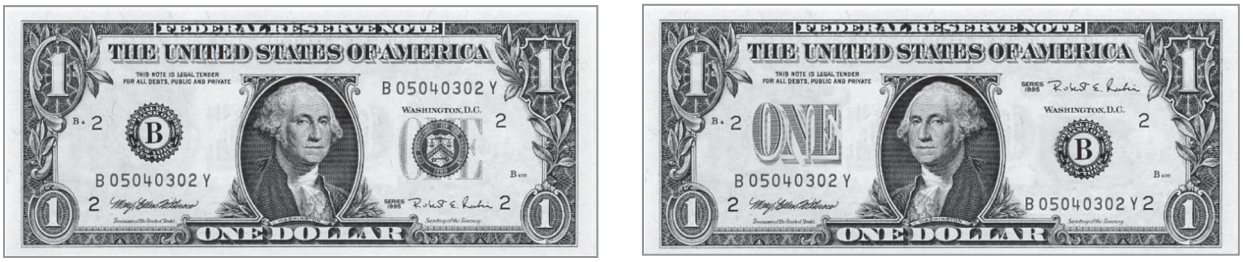
Contrast frequency filtered image euro 10 | Colour filtered image euro 10



a) b)

Figure 5.13
Spatial lay-out and colours are differently processed. Fabricated images of early image processing within the brain of banknote of 10 euro, model 2002 (De Heij, 2010a).
a) Impression of an image of a banknote of 10 euro filtered on high contrast frequencies.
b) Impression of an image of a banknote of 10 euro filtered on colour.

Which is the correct USD banknote?



a) b)

Figure 5.14
People do not recall the correct one dollar banknote. Which is the correct USD banknote, a or b?

The portrait functioning as an authenticity feature of banknotes (UIF 1) has been introduced. Later, in the 1920s, portraits received another role and should support confidence (UXF 3), as introduced in subsection 1.3.3. The function of portraits on modern banknotes shifted once more, this time from supporting confidence (UXF 3) to emphasise the identity of the nation (UXF 1). Finally, a main image, like a portrait, may also bond the user to a banknote (UXF 4). Summarising, a portrait may serve up to four user functions (UIF 1, UXF 1, UXF 3 and UXF 4). However, a portrait is not a design element in its own right and may therefore be omitted.

In general, the first portraits looked to the left or to the right, away from the holder of the banknote. Over time, portraits turned their face towards the banknote user, illustrated by figure 5.15. The next development was that portraits not only made eye contact, they also showed a little smile (figure 5.15h). Banknote designers should take care; while a modest smile is allowed, laughing people, cartoon figures or children should not be used as this is experienced as being at odds with banknotes being a serious product, diminishing confidence in banknotes (De Heij, 2007). Future portraits will probably zoom in further on the central area of the face, the imaginary parallelogram which can be drawn between both eyes and the mouth, which includes the nose, the same area as used for biometric face recognition. A prediction can be made about the next, fifth step: future portraits will probably show the teeth (figure 5.15j).
Summarising, the portrait development on banknotes has gone through five stages: size (1), making eye contact (2), showing a smile (3), approaching the observer (4) and showing teeth (5).

The embodiment of a portrait is one more design parameter and may range from a classical portrait gravure to an innovative portrait gravure. The portraits designed by Robert Oxenaar were a novelty, both from a design and gravure aspect; comparing figure 5.16b with figure 5.16a will make this clear. Oxenaar's designs used the gravure press to a maximum; his portrait designs of Dutch national heroes are made of bold, wide engraving lines with a high tactility combined with the thinnest printable lines. Such designs are - in retrospective - fine examples of the advices on 2D-design in the beginning of this subsection, using high contrast edges and high resolutions. These gravures were not only technically outstanding, they also elicit a little smile (UXF 4), a sign of the time, as traditional authorities were challenged in the 1960s. On top of that, several private jokes were worked into the Dutch banknotes, like Oxenaar using his fingerprint for the gravure of the hair of Spinoza (De Heij, 2012).

Answer to the question of figure 5.14: Washington looking to the right is correct (figure 5.14a).

Development of portraits

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

Figure 5.15
Impression of the development of portraits on banknotes. Selection made by the author.
a) Scotland, one guinea (21 shilling), portrait of King George III (1738-1820), issued in 1777.
b) France, 500 livre, portrait of Louis XVI (1754-1793), issued in 1790.
c) Ireland, IEP 1, portrait of a woman, believed to be Hazel Lavery (1880-1935), issued in 1928.
d) Netherlands, NLG 25, portrait of Willem Cornelis Mees (1813-1884), issued in 1934.
e) Israel, 5 lira, portrait of Albert Einstein (1879-1955), issued in 1968.
f) Denmark, DKK 500, portrait of Franziska Genoveva von Qualen (1776-1841), issued in 1972.
g) Switserland, CHF 10, portrait of Leonard Euler (1707-1783), issued in 1979.
h) Germany, DEM 100, portriat of Clara Schumann (1819-1896), issued in 1994.
i) Gibraltar, GIP 10, portrait of Queen Elisabeth II (born 1926), issued in 2011.
j) Papierfabrik Louisenthal, portrait of Yvonne, promotional banknote (2010).

In the 1970s, the 100 gulden was the most frequently counterfeited banknote in the Netherlands. By creating an *emergency banknote*, DNB anticipated on this situation and asked Oxenaar to design such a note (Bolten, 1999). A portrait was not specified and Oxenaar was free to propose a theme. As counterfeits of the existing model, the NLG 100/De Ruyter, kept on being accepted, the design prepared was taken into production. The result, the NLG 100/Snipe (figure 5.16c) became very successful; the word Snipe became synonymous for 100 gulden. The popularity of the Snipe will be reviewed in more detail in subsection 6.2.1 and section 6.7. Because of its success, the bank kept a high design freedom for subsequent banknote designs (section 1.1).
The introduction of the Snipe was not the result of perception research, but the result of the intuition of the designer. At international the design received skepticism, and representatives of DNB received questions like "What is the facial expression of a snipe?" (Koeze, 2003b).

Since 1992, neuroscientists are in discussion whether there are specific areas in the human brains, which are specialised in facial recognition, indicated by the Fusiform Face Area or FFA (Sergent et al., 1992).
Eagleman (2017) agrees: "The human brain is massively specialised for faces, but has little neural real estate devoted to edifices". However, this does not seem to be enough evidence for promoting portraits on banknotes, as reported by Ward et al. (2008, study reported in De Heij, 2009). In a study on four different main images on a banknote, a portrait came out as the least guiding to authenticate an image, the others were an animal, building and a manmade product. In 2011, German respondents, using the euro, were asked for their favourite image category (Müller, 2011). Like in Ward's study, a building was preferred over a portrait, animal or flower: "Regarding the motifs elderly seem to have become accustomed more to architectural images, as 56 % preferred the images of a real building".
In 2009, the euro banknotes circulated for seven years in the Netherlands and the Dutch were asked about what they recalled of the images on gulden banknotes. Best recalled were "snipe", "lighthouse" and "sunflower", as reported in figure 6.6. This study is supporting evidence that a portrait is not better recalled than a bird (snipe) or a building (lighthouse) or a flower (sunflower).
One more study questions the use of portraits (Masuda et al., 2016). Object of study was to what extent a printed portrait contributes to the perceived genuineness of a banknote. The main conclusion was that about one third of the respondents did not pay attention to any part of the portrait. Respondents who did look at the portrait first zoom in on the eyes, followed by respectively the mouth, nose, hair, cheek and forehead.

Western banknotes may display portraits, but for long banknotes in Islamite cultures did not, until portraits appeared on modern banknotes issued in Indonesia, Morocco, Pakistan, Saudi Arabia and Tunisia (for some examples: De Heij, 2012). However, the introduction of a bird as a main image on a Dutch banknote in 1981 marks the start of an ongoing trend to abandon portraits. New banknotes issued in Russia displayed buildings (1991), followed by animals in South Africa (1992) and Tanzania (1997). At the time of the preparation of the first series of euro banknotes all European countries displayed portraits on their banknotes, except for the Netherlands (De Heij, 2012). After the euro followed Bermuda (2009), Denmark (2009), Nicaragua (2015), Argentina (2016), Switzerland (2016) and Norway (2017). South Africa reintroduced portraits on the front in 2012 (figure 4.3a).

Although there is a trend to replace portraits by other images, central banks may still believe in a portrait as an authenticity feature, evidenced by the following recent statement made by the Bank of England: "People will notice when a face looks wrong. There is something about portraits that make us more alert to changes." (Sharman, 2014). A statement confirmed by a banknote printer: "Especially the eyes are unique for a portrait gravure and some believe that the public would spot counterfeits more easily because of a different 'look' in the face." (De La Rue Currency, 2014).
The second series of euro banknotes, the Europa Series, introduced two small portraits. "People tend to recognise faces intuitively" is the argumentation given (European Central Bank, 2013e).

In the end, the valid argument for a portrait seems to be that people like to look at other people and therefore they will probably focus their eyes on any - small or large - portrait on a banknote.

From traditional portrait to banknotes without a main image

a)

b)

c)

d)

Figure 5.16
The honouring portrait on Dutch guilder banknotes was abandoned in three steps.
a) NLG 100/Erasmus, 1953. Classic portrait gravure. Designer: J.F. Doeve.
b) NLG 100/Michiel de Ruyter, 1972. Alternative portrait gravure with bold engraving lines; slightly caricatured. Designer: R.D.E. Oxenaar.
c) NLG 100/Snipe, 1981. Designer: R.D.E. Oxenaar.
d) NLG 100/Little Owl, 1992. Designer: J.T.G. Drupsteen.

Are these banknotes real?

Figure 5.17
Euro banknotes with changed main images. Images prepared by Joh. Enschedé in order of DNB (2008).

Answer to question of figure 5.17: images of euro 5 and 50 are switched. Image of euro 100 is applied to the euro 10 and the image of the euro 200 on the euro 20.

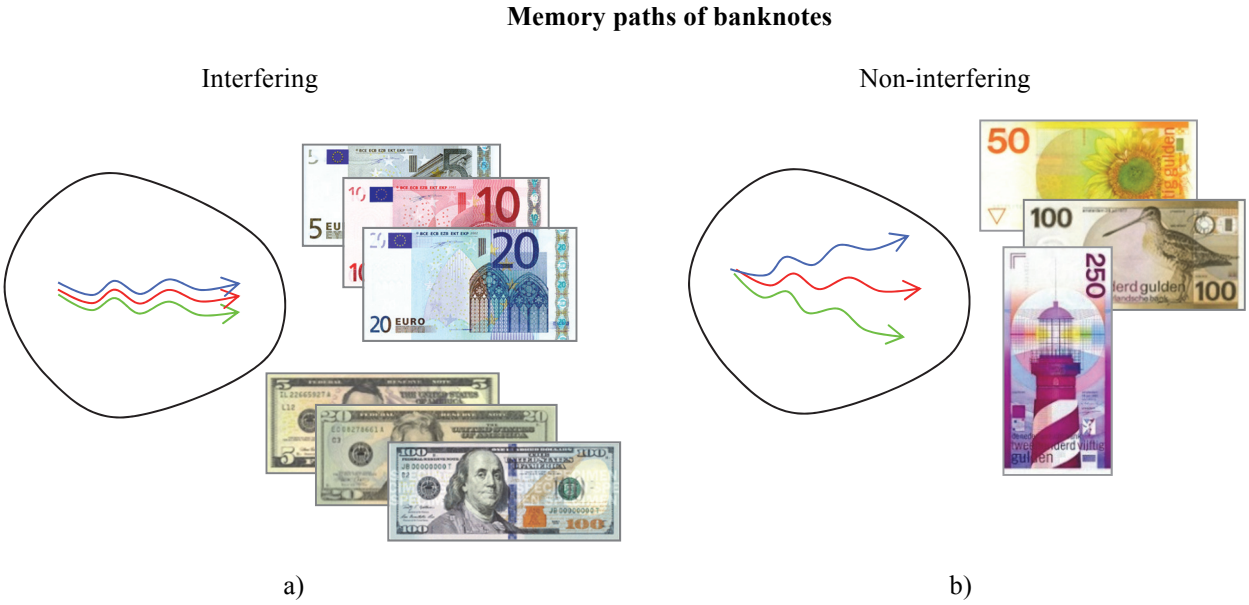


Figure 5.18
Illustration of different of memory paths of banknotes
a) Quite similar memory paths for banknotes being part of the euro and US dollar series.
b) More divergent memory paths of banknotes within a series with more variables in the theme.

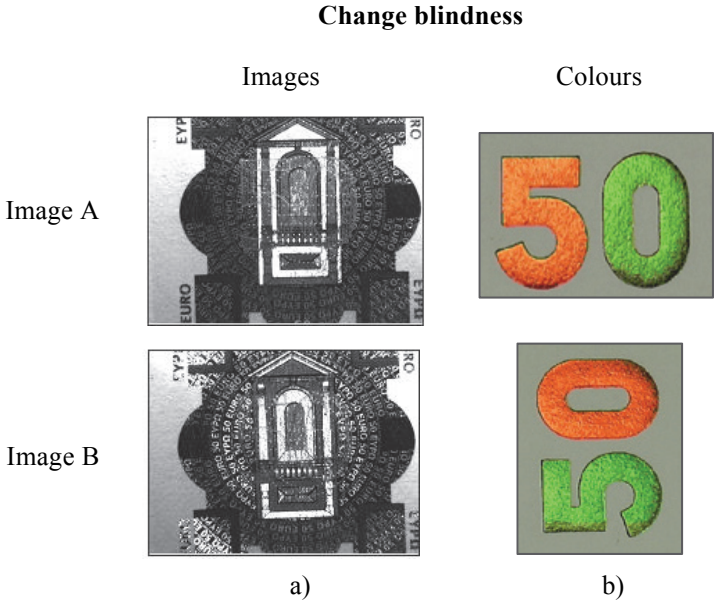


Figure 5.19
Two examples of change blindness with optical authenticity features.
a) A switch from dark to light within the Renaissance window is seen when the hologram on a banknote of 50 euro is tilted in east-west directions. People seem not to be able to remember what was light first and became dark and vice-versa (De Heij, 2010). Image: Javier Gamo.
b) Unique colours permutation is revealed when a 90°rotation is applied. Sample produced by Hologram Industries, around 2004.

Another aspect of a portrait design is its place between other portraits within a series of banknotes. People may favour portraits or buildings, within a series it is better to use both.
To provide differences between the portraits in the series "Forebears II" (Bolten, 1999), Oxenaar added distinguishing design elements like a hat or collar. Oxenaar also designed one portrait looking to the left and another to the right. Either way, for the Dutch it was not enough to distinguish between the different portraits, as concluded in 1985 in a study carried out by Wagenaar (a summary of the study is reported in De Heij, 2007). The banknote's colour has been eliminated in the stimulus material, images were offered in grey scale to 100 respondents. The outcome was that 55% of respondents knew from which denomination the portrait was taken. In a second study Wagenaar offered banknotes from the series "House-Tree-Animal" and included also one with a portrait (figure 1.1). This time the score was much higher, far over 90 %.
The two studies by Wagenaar delivered two conclusions. First, when banknotes carry similar images, like portraits, it is difficult to recognise these images without colour information. Second, the use of different themes within a series will improve the recognition of denominations. Furthermore, the study concluded that subthemes should not overlap with the main theme or subthemes of other denominations.

Euro banknotes all carry images of buildings and with the help of Photoshop images on euro banknotes were switched, as shown in figure 5.17 (De Heij, 2009; 2010a; 2010c). Most respondents were not able to distinguish that the banknote images had been changed; the measurement results of this study are reported in subsection 6.9.1. This phenomenon is explained by interference of *memory paths*. A memory path is the route to a specific piece of memory. Interference of memory paths is schematically indicated in figure 5.18 (De Heij, 2010a). Images taken from the same image category will lead to interference, as illustrated by figure 5.18a. Images representing different image categories are expected to be less sensitive to interference, illustrated by figure 5.18b. The advice to apply main images from different image categories has been followed in 2014 by Norway's central bank (subsection 3.5.1). Each denomination within this series displays a theme and the accompanying main image is selected from a different image category, contributing to UIF 1.
The more frequent a specific banknote design has been used, the better its images will be stored in the long-term memory. This explains why to the Dutch Snipe = 100 and 100 = Snipe.

5.4.5 Perception of public authenticity features

The previous sections introduced the perception of main images on banknotes, unveiling the problem of inattention. People may operate user functions in autopilot, without much attention. However, when it comes to an authenticity check (UIF 3), inattention is a problem. Eagleman (2017) argues:

> "The heart of the problem is that notes are jam-packed with decorative features that have nothing to do with the security: the trees, the patriots, the birds, the flags, the swirling colours. No one notices the security features because of all the distractions. A piece of security, I suggested, should be a blank white piece of paper with a single hologram in the middle. That's it."

Indeed, the focus of perception studies is mainly on public authenticity features (UIF 3). Banknote designers aim for a different 'feel and look' between real and false notes. This difference should be large enough for people to distinguish the differences, to understand it and to make their decision. Not an easy task, as a counterfeited banknote may be held for genuine and a genuine banknote for a counterfeit.

The experiences with the Dutch biannual public opinion polls on banknotes (subsection 2.10.3) learn that people find it difficult to put authenticity features of banknotes into words (De Heij, 2007). *Linguistic determinism* explains that people may only recognise something as far as language allows them to do so. Authenticity features can be designed as a *realistic image* or as an *abstract image* and

banknote designs offer examples of both categories. Abstract designs of watermarks are found in Dutch banknotes, like the watermark “waves” in the NLG 25/Sweelinck (1972) and the watermark “stereo” in the NLG 1,000/Spinoza (1972). Later Oxenaar introduced animals, like a bird (NLG 100/Snipe, 1981), a bee (NLG 50/Sunflower, 1982) and a rabbit (NLG 250/Lighthouse, 1986).
To find out which type of images the Dutch public would prefer, a dedicated study to realistic or abstract images was initiated in 1986 and conducted by Wertheim (study reported in De Heij, 2007). The study included also numerals (like 10). Respondents were shown a main image, like on a banknote, surrounded by smaller items, being both *figurative* and *non-figurative*, abstract designs. Two types of figurative elements were used, with and without a relation to the main image. Such a relationship can be a *linguistic relation* or a *shape relation*. An example of a linguistic relation is the saxophone printed on the Belgian 200 franc note, bearing the portrait of Adolphe Sax (1814-1894). Examples of *shape related features* are a sunflower and a straw hat. The keyboard of a piano and a crosswalk is one more example of shape related things. Shape related features can also be abstract, like geometric shapes (ovals, stars, circles etcetera).
The outcome of Wertheim's study was that all figurative pictures were more easily recalled than the abstract ones. A second finding was that, when it comes to the recall of features, no difference was found between the related figurative images and the non-related. These studies were input for the design of the Abstract Series by Jaap Drupsteen, of which the first banknote was issued in 1989 (figure 1.2). The public features in this series are designed by using realistic images like a poppy flower and a mouse. The banknote models received their name from the watermark designs, which were all birds. The birds were selected by an association with the main colour of the note, for example a Robin for the reddish NLG 25. Furthermore, the name of the feature was printed next to it (subsection 3.5.1).

The design of tilt features is usually based on changing images or changing colours and it is rather unknown how such features should be designed user-friendly. From the literature, it is known that people can be perceptually blind to images changes, like in the case of the mirrored portrait of George Washington (figure 5.14), a phenomenon known as *change blindness* (Shore and Klein, 2000).
Tilt features are either based on changing images or on changing colours and the two may also be combined. For both categories people experience difficulties to recall and/or perceive what has changed after they have tilted the banknote. An example of the perception of change blindness within an image is provided in figure 5.19a. People may not recall image A by the time this image has changed into image B. Figure 5.19b provides an example of an image change based on a colour switch. The figure 50 shows a green 5 and a red 0, but when it is rotated by 90°, these colours switch and people do not remember what they have seen, was it a red 5 and green 0 or a green 5 and a red 0?

Colour is the most important design element of a banknote as elaborated on in the subsections 3.2.3 and 5.2.1. Therefore, one may expect that authenticity features based on colour would be successful. However, this is not the case; public feedback polls report low scores for colour-changing features (subsection 6.4.2). First, the verification of a deviant colour change will be troubled, as it is difficult to remember the original colour-flop from A to B when verifying a fake colour-flop from A' to B'. People may remember red, but they cannot tell whether it was merlot, scarlet, mahogany or cherry blossom red. Second, the perception of colour changing features strongly depends on light conditions. Crumples may further disturb the colour perception, especially of glossy colours.
Third, colour differences between two changing colours are not large enough to be perceived. The difference between two colours A and B is expressed by Δe, the result of a formula based on spectral values within the “L*a*b*-chromaticity diagram” (Judd and Wyszecki, 1975). Colour deviations are clear for an average human observer when $\Delta e > 6$ and will be barely perceptible for $\Delta e < 1$, as provided by the information in figure 5.20 (Huijsing, 2001). An acceptable match in commercial reproductions is achieved when Δe is between 3 and 6. Usually colour-flops in banknotes do not seem to reach $\Delta e > 6$.
Human perception is more sensitive to colour differences, when two colours are touching each other, a principle not used in banknote design (for an example see De Heij, 2010a).

The design of a colour changing feature is another perception parameter. Several central banks opted for the numerals to be printed in a colour shifting ink, like the numerals on the South African rand (2012), the euro (2013) and the Chinese yuan (2015), all printed with the same ink, known as “Spark”. This ink changes from green to blue and shows a rolling bar when moved. Other central banks applied geometric designs, like Uganda (2011) and Norway (2017), or applied a realistic design like a bear, the national symbol of Russia (2010) or introduced theme related design elements, like a book or a ship (Sweden, 2015). Which of these designs offers the user the best judgement on a genuine colour shifting effect remains unknown.

A banknote seems a simple piece of paper, but designers often don’t realise that a person may observe a banknote in 16 different viewing positions. A banknote can be looked at from the front or the reverse, creating two positions. As a banknote is slightly transparent, the banknote can also be perceived in reflection or in transmission, bringing a total of four viewing positions. Furthermore, a banknote can be hold with the upside down, bringing the total to 8 viewing positions. Finally, the note can be hold in portrait or landscape position, which leads to 16 viewing positions.
User functions are not equally spread over these viewing positions. The four most relevant are presented in figure 5.21, the front and the reverse, both in reflection and transmission. As the front usually provides enough information to use a banknote (UIF 1), people tend to look only to the front. In general people don’t turn a banknote to look at the reverse. Usually, the back serves for some public authenticity features (UIF 3) and is mainly filled with communication messages (UIF 4).

Banknote designers seem to follow the same sequence as the public, they tend to design the front first, followed by the design of the back. Designers do not pay much attention to *transmission design,* usually delivering an unorganised impression. Transmission design is relevant, especially to retailers, who may ‘park’ a just received banknote on a transparent counter. When carefully designed, for example by grouping look-through features, a retailer may check in one glance several look-through features while preparing the change, features like a watermark, thread, clear window or a see-through register.

Collective use of banknotes implies that people must trust each other on the genuineness of banknotes. An obvious self-check may therefore be experienced as impolite, as if a person checking a banknote does not trust his fellow citizens and people may feel offended. Feel, the first check of 'feel, look and tilt' can be done discreetly, but the action of look brings the first hesitations. People must hold the banknote up to the light for look-through, an obvious action which may hold people away from this type of authenticity self-checks. The Bank of England advocated that such action should be normal behaviour and should not be experienced as offending or mistrust (figure 5.22a). A watermark goes back to the time that banknotes were mainly used by merchants and within this user group a look-through action was probably accepted. However, central banks do not take the public’s reluctance to obtrusive authenticity checks into account. Many new features ask for human actions which cannot be done secretly, like in case of the “hidden numbers” in the polymer banknotes of the Bank of Canada (figure 5.22b). The window-feature in the euro 20, part of the Europa Series, can also not be verified unobtrusively (figure 5.22c). Feel and look-at features should be developed instead of look-through and tilt features, as these features better match user requirements of public authenticity features (De Heij, 2010a).

PERCEPTIBLE COLOUR DIFFERENCES	
Colour difference Δ e	**Visual effect**
Δ e < 3	Hardly perceptible
3 < Δ e < 6	Perceptible
Δ e > 6	Good perceptible

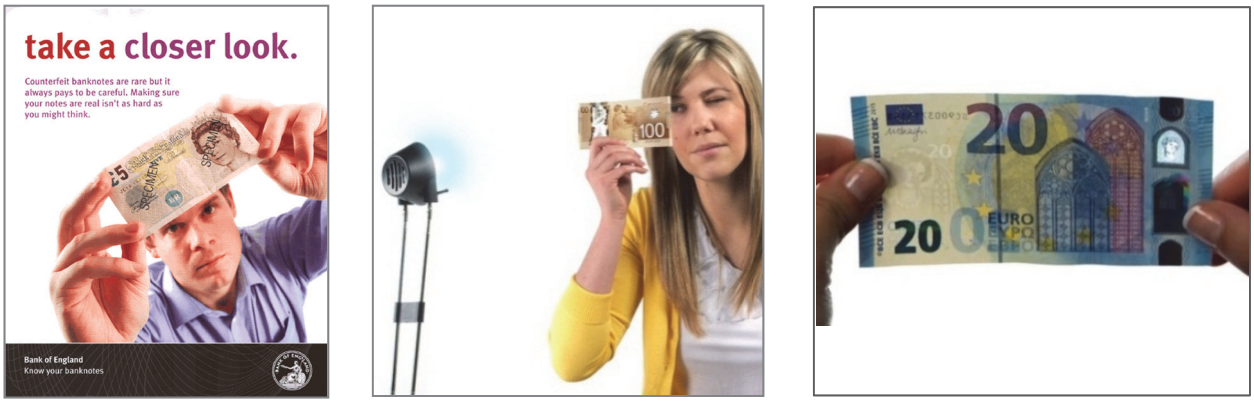
Figure 5.20
Perceptible colour differences in terms of Δ e.

VIEWING POSITIONS		
	Front	**Reverse**
Reflection	UIF 1, UIF 4	UIF 4
Transmission	UIF 3	UIF 3

Figure 5.21
The most four relevant viewing positions of a banknote.

Obtrusive authenticity self-checks

Bank of England, 2006 | Bank of Canada, 2011 | European Central Bank, 2015



a) b) c)

Figure 5.22
Central banks promoting obtrusive methods for an authenticity self-check by the public.
a) Checking a watermark in transmission. Image: Bank of England.
b) Checking 'hidden numbers' in a polymer banknote, using focussed light, e.g. a halogen lamp. Image: Bank of Canada.
c) Checking a 'window' with the portrait of Europa in the redesigned euro 20. Image: public domain.

5.5 The 4M Model for the Perception of Banknotes

When people pay attention to a banknote, they are in *banknote mode*. In this mode, people may perceive a banknote either in *configural mode* or *feature mode* (Asch, 1946). In configural mode people perceive the complete banknote as one object, without resting the eye on details (subsection 5.3.1). In feature mode people focus on a specific Region of Interest, like a numeral or figurative image.
Instead of configural mode, the preferred term within this thesis is *full image mode,* which is more appropriate to the opposite term of feature mode.
Next to banknote mode, a *brain mode* is introduced, which also consists of two modes: *automatic mode* and *controlled mode* (Kahneman, 2011). When the information on a banknote is processed fast, people are in automatic mode, like driving a car or walking a stair. When people are looking more careful to a banknote, the brains are in controlled mode. These two modes refer to Kahneman's *System 1* and *System 2*, the first operating fast, the second slow.
Bringing the two variables of banknote mode and brain mode together, a recognisable model for banknote designers is created, presented in figure 5.23, the *4M Model for the Perception of Banknotes* (De Heij, 2015b; Currency News, 2016b).

In the first quadrant (M1) people do not give attention to a banknote and may get fooled. An illustrative example is "Paying with paper" by Brown (2007), a movie available on the internet. Brown distracts the payee while paying, so that the payee is not attentive and accepts blank paper. Specific banknote features prompting the subconscious authentication, of the banknote are called trigger features, already introduced in subsection 3.4.3 (De Heij, 2006a; 2010a). An example of a trigger feature is the paper colour of a banknote; people may be triggered when this is absent (for more trigger features: De Heij, 2010a). Paper tints are introduced in subsection 3.2.3 and different paper tints were applied in the first series of euro banknotes. In the second series, all denominations received the same paper tint, because of reasons for fitness sorting.
The second quadrant (M2) represents the user situation of a quick authenticity self-check on one or two of the payee's favourite features, like a check for a thread. Quadrant three (M3) concerns the situation that a just received banknote is compared to another similar banknote. Quadrant four (M4) represents a proper authenticity self-check following the instruction of the central bank's leaflet.
The first situation (M1) seems to be the most common one; people handle banknotes in full image mode and in automatic mode and are unaware of any mimicked banknotes. The 4M Model demonstrates that giving attention to any feature in a banknote depends on three variables:

1) User function mode (either in using mode or in experiencing mode),
2) Banknote mode (full image mode or feature mode),
3) Brain mode (automatic mode or control mode).

The 4M Model defines four modes of giving attention to a banknote. Attention can be given to any of the user functions and the combination of attention and a specific user function is the *Attention Function Mode,* which is different from the User Function Modes as introduced in section 2.7. The User Function Mode describes the combination of user group and user function, like a member of the public identifying the banknote's value (UIF 1). The Attention Function Mode combines one of the four attention modes with a user function, for example no attention is given to authenticate a banknote (UIF 3); situation M1 in the 4M Model.
In theory there are 40 different Attention Function Modes, as the Model for Use-centered Design of Payment Instruments identifies ten user functions and each user function may be perceived in four different Attention Function Modes. Combined with the 60 User Function Modes, introduced in section 2.7, there are 2,400 possible usage situations of a banknote. However, most often people will operate a banknote in M1; for value recognition, they take a quick look (automatic mode) at the full image of the banknote (banknote mode). Recognising the value of a banknote is the most frequently operated user function and this information will be processed in *recognising value mode* or *denomination mode* (UIF 1). Checking a banknote whether it is genuine or fake, people are in *checking authenticity mode* (UIF 3).

4M MODEL FOR THE PERCEPTION OF BANKNOTES		
Brain mode	**Banknote mode**	
	 Full image mode	 Feature mode
Automatic mode (fast)	**M1** **No attention** *Paying with blank paper** *Trigger features*	**M2** **Attention to single feature** *Thread or watermark*
Controlled mode (slow)	**M3** **Attention to complete banknote** *Compare with another banknote*	**M4** **Dedicated attention** *Following central bank leaflet*

**) Movie by Derren Brown (2007), available on YouTube.*

Figure 5.23
The 4M Model for the Perception of Banknotes. A model of the 4 Modes of giving attention to a banknote. In italics, an example is provided for giving attention to a banknote in checking authenticity mode.

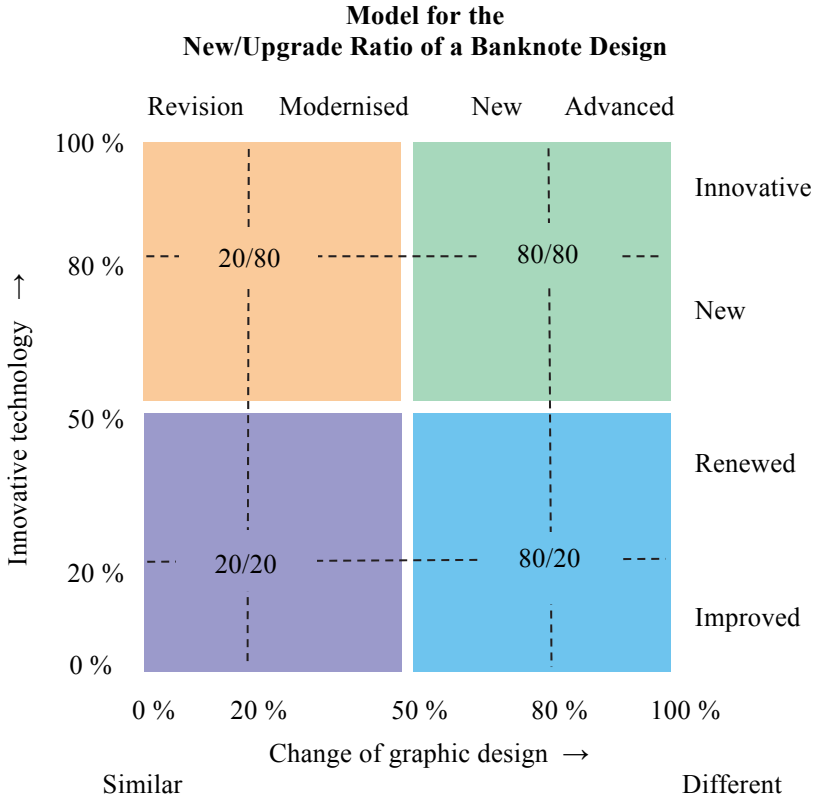


Figure 5.24
The Model for the New/Upgrade Ratio of a Banknote Design. Banknote design policies based on two variables: change of graphic design (x-axis) and innovative technology (y-axis). Four basic design policies are represented by respectively different values for a design change and the introduction of an innovative technology. The figure 20/80 indicates respectively a design change of 20 % and a technology change of 80 %.

5.6 Attitude towards new banknote designs

A banknote can only be perceived in detail when people pay attention. Attention is influenced by people's attitude towards a banknote, which is characterised by a *wait-and-see attitude*, a settled way of thinking about a banknote, illustrated by a statement made by a former director of the US banknote production facility (Pacreu, 2008):

> "I believe that in most cases the public is not concerned and does not really look at their banknotes".

This wait-and-see attitude towards banknotes is explained by three psychological phenomena. First, there is the *satisfice principle*, a contraction of satisfy and suffice, as introduced by Simon (1956). People are satisfied with limited changes and do not make a fully rational choice for the optimal, the banknote is good enough. People expect to use banknotes without any trouble, like their expectations on the use of water from the crane or taking public transport.
Second, banknotes are an *easy sell* in the Gourville matrix, as a new banknote requires limited behaviour changes (Gourville, 2006). People do not have to adapt and will use the new banknote like the previous one. Changing the positions of a standard QWERTY-keyboard is in Gourville's matrix an example of a *sure failure*; although the design changes are small, people must change their behaviour tremendously.
These two observations lead to the question of whether there is a need for a new banknote? Subsection 1.3.2 reported on the public's reluctance concerning the need for new banknotes, which is supporting evidence for the wait-and-see attitude.

5.7 Model for the New/Upgrade Ratio of a Banknote Design

Seeing an upgraded banknote for the first time, people may react by 'we already have this note', a phenomenon which is explained by people's inner image of a banknote (subsection 5.4.3). As a result, people may not be interested in the upgraded banknote. Another drawback of an upgrade is people's first reaction of 'it looks phoney', an example of the heuristic quality (subsection 5.4.1). Unlike an upgrade, a completely new design creates a new category prototype, which has a better chance to find a permanent place in the long-term memory.

An adage in consumer behaviour research is the MAYA-principle, an abbreviation of Most Advanced, Yet Acceptable, coined in the 1930s by industrial designer Raymond Loewy (1893-1986). Later studies confirmed this principle of consumers being, on the one hand, positive about novelties in design, but on the other hand, these innovations should not be taken too far (Schoormans and Robben, 1997). The MAYA-principle provides an explanation for people's wait-and-see attitude towards new banknote designs (section 5.6). The public is positive about new banknote designs, as it increases their confidence (UXF 3), but a new banknote design should not be too innovative, it should have one foot in the past and one foot in the future (Infosecura, 2007).

Like other products, a new banknote design can be characterized by its technical innovations and design renewal. The options are clarified with the help of the *Model for the New/Upgrade Ratio of a Banknote Design* provided in figure 5.24 (De Heij, 2012; 2013a; 2017a).
Four different design policies are distinguished, representing four different *new/upgrade ratios*. A new/upgrade ratio consists of two figures, expressing the percentage of change of respectively the graphic design and the technical innovations. The minimum change for both parameters is suggested by the author to be 20 %, otherwise there is no reason to issue a new banknote. The figure of 20 % is inspired by the well-known 80/20 rule by Pareto, originally an economic observation, made in 1896 by Vilfredo Pareto (1848-1923). Pareto observed that 80 % of Italy's land was owned by 20 % of the population. Later the 80/20 rule was also applied by others. For example, in engineering it is a well-known statement that by fixing 20 % of the most-reported failures, 80 % of the related errors and crashes are eliminated.

Because of the MAYA-principle the maximum change, in this Model for the New/Upgrade Ratio, is set at 80 %.
Applying the new/upgrade ratio, currencies can be positioned in different quadrants.

Larger currencies are found in the purple 20/20 quadrant, like the Chinese yuan, the Indian rupee, the US dollar, the Japanese yen and the euro. In general, such upgrade designs are the existing banknote design with one or two new authenticity features (UIF 3). Redesigns fail on the primacy effect (section 5.4). Furthermore, an upgrade does not bring new identity aspects (UXF 1). Moreover, the design quality of upgrades is often inferior to the quality to the original, among designers known as 'a cut-and-paste job'.
It will be apparent that new and advanced designs will attract more attention than revised or modernised designs and will therefore have a higher probability that some pieces of (new) information will be stored in the long-term memory. This doesn't have to be any of the promoted information. For example, people may recall the first time they held a euro banknote in their hands-on the first of January 2002 and may not remember any of the promoted public features.

Opposite of the 20/20 quadrant there is the green 80/80 quadrant. Banknote designs positioned in the 80/80 quadrant will probably receive more interest, including interest for the innovative features. Larger central banks are not part of this quadrant and it seems that only smaller central banks tend to opt for the green 80/80 quadrant, like the central banks of Denmark, Norway, Sweden and Switzerland. At the times of the Dutch gulden banknotes, the Dutch central bank also aimed for new banknote designs within this quadrant. Two banknote models are a text book example for this quadrant, the Dutch 10 gulden issued in 1971 (figure 3.5) and the Australian 10 dollar issued in 1988 (figure 5.25). The Dutch banknote introduced several innovative features for automatic control and showed an innovative design. The Australian banknote was the first to be printed on a specially developed synthetic substrate, including a transparent area, introduced in subsection 4.6.1. In the opinion of the author the design of the Australian banknote was less advanced than the design of the Dutch banknote; the image of an Aboriginal was a novelty (UXF 4), but the graphic design was traditional.

With regard to technical innovations, two criteria are possible. A new banknote may be the first to apply a new technology, such as the polymer substrate in Australian banknotes issued in 1988. Secondly, a central bank can be innovative compared to an earlier own issue. Application of polymer in Canadian or English banknotes is innovative for these currencies, but is worldwide not a prime. The application of a very wide foil stripe, surrounded by large transparent areas, within a polymer substrate is an innovation, carried out first in the Canadian banknotes (figure 2.5b).
The second criterion seems most relevant. The goal is for the users of a currency to get technically renewed notes and it does not matter if these are real innovations or a borrowed application. Within the world of central banks, a central bank will really get the attention when it applies a whole new technology.

Several central banks issued their designs on new synthetic substrates or multilayer substrates, as introduced in subsection 4.6.1. However, as such designs are kept close the previous designs, these banknotes are representatives of the orange 20/80 quadrant, like the SLZ 100 and 200 issued by Swaziland in 2008 and the KZT 10,000 issued by Kazakhstan in 2015. When development costs are an issue, central banks could opt for the blue 80/20 quadrant. With relatively limited costs, a new banknote design can be prepared.

Innovative banknote, Australia (1988)

a) b)

Figure 5.25
Australian 10-dollar polymer banknote (1988). This is a highly innovative banknote, as it is printed on polymer instead of paper. Furthermore, the note includes two innovative authenticity features, a transparent window and specific hologram (Pixelgram), viewable from both sides.
a) The front of the note shows the Supply, a ship from the feet which landed at Botany Bay in January 1788, with a line of immigrants and the site of the first settlement at Sydney cove in the background.
b) The reverse celebrated Aboriginal culture with designs based on work commissioned from Aboriginals artists; the main features were an Aboriginal youth, an ancient rock painting, hand stencils and a ceremonial morning stare pole.

5.8 Concluding remarks on the perception of banknotes

Knowledge on user behaviour with banknotes is essential for a use-centered design approach and includes perception topics. However, there is no dedicated theory on cognitive processing of banknotes. Information about banknotes arrives in the human brain by visual and haptic stimuli, a case of multi-sensory input.
There are several methods supporting insights on human reactions on a banknote design. However, they all seem to be at their infancy.

Several contributions have been made to increase insights in user behaviour with banknotes. The main contribution is the "4M Model for the Perception of Banknotes", combining parts of the work of Asch (1946) and Kahneman (2011). The 4M Model defines four different Attention User Modes. As there are 10 user functions, there are at least 40 possible situations of giving attention to banknotes. The most common situation seems to be perception of banknotes in denomination and/or handling mode. In these two User Function Modes, people will perceive a banknote in full image mode. Only when triggered people may check a banknote in feature mode, like in case of an authenticity check (UIF 3) or communication message (UIF 4).

Another contribution is "The Model for the New/Upgrade Ratio of a Banknote Design". New banknote designs can be classified according to their new/upgrade ratio, two figures representing the level technical innovation and the level of design changes. Changes in the design will attract more attention than changes in the production technique. With new designs people will have to create a new inner image of their banknotes. Banknote designs should not deviate too far from what people may perceive as a banknote, a rule of thumb is that the maximum design change can be 80 %. However, in general people are not looking forward to a new banknote design; any public attention for banknotes is hindered by a wait-and-see attitude towards new banknote designs.

In addition to these suggestions on model building, this chapter provides an overview of the knowledge gained on the perception of banknotes, suggesting that:
- Main images within a series of banknotes - if any - should be selected from different image categories. If so, the main image will contribute to recognition of the banknote's value (UIF 1).
- No evidence is found that people will perceive disturbances in a portrait better than a similar type of disturbances in images of other categories, including changes around the eyes.

- Designers usually put most effort on the front of the notes, followed by the reverse and have little eye for their designs when viewed in transmission.
- Tactile structures positioned on the banknote's back will improve the instant recognition of genuine banknotes (UIF 3, in automatic mode).
- According to linguistic determinism, people may only remember design elements of a banknote when they have a name. This is relevant for the series theme, the theme individual banknotes and the public authenticity features.
- Instead of look-through and tilt features, feel and look-at features should be developed, as they match the user experience requirement of a delicate authenticity check.
- People experience problems with the perception of tilt-features (images, colours).
- Monitoring eye movements during the design process are useful as they provide design feedback, so that changes of the design can still be made.

Without data you're just another person with an opinion.
(William Edwards Deming, 1900 - 1993)

CHAPTER 6
MEASUREMENTS REPORTED ACCORDING TO THE UPID-MODEL

6.1 Introduction

Central banks may collect user feedback on their banknkote designs, which is still not often done. If such studies have been carried out, central banks are reluctant to publish the results.
Since 1981, user feedback on banknotes has been biannually collected in the Netherlands and the results have been made public from the start. A range of *longitudinal measurements* have been carried out, covering the period 1981-2017, which is unique within the banknote community. Overviews of the longitudinal measurements and the *single examinations* are presented in respectively figure 6.1 and 6.2. These measurements relate to gulden banknotes (1981-2001) and to euro banknotes (2002-2017). An overview of all studies done by the author, studies related to banknote design, is provided in Appendix 1; publications by the author are listed in the author's publications, part of the references. Since 2013, the original reports by the contractors have been published (Visser and Dijkers, 2013; Randsdorp and Zondervan, 2015; Klöne and Zondervan, 2017).

The question to be answered in this chapter is whether the Model for Use-centered Design of Payment Instruments, the Upid-Model, delivers a framework to report the measurements from the users' perspective. And if so, do the measurements discriminate between the user functions as realised in different banknote designs?

In general, most literature on the assessment of user functions of banknotes concerns the function of checking authenticity (UIF 3). The design of public authenticity features was subject of study, answering the research question whether public features should receive an abstract, figurative or realistic design (Wertheim, 1990; study reported in De Heij, 2007). Preferences for either foil or colour features are reported (Setlakwe and DiNunzio, 2004). The National Research Council explored new banknote features for new US dollars, studies which have been made public (National Research Council, 1985; 1987; 1993; 1995; 2007). Interaction and intuition are two variables of an authenticity check, which have been presented in a Cartesian plot (Firth and Balodis, 2011). Longitudinal measurements are available for the confidence of Canadians in their banknotes, part of measurements carried out on UXF 3 (Bank of Canada, 2009; 2017). Whether the banknote's quality in circulation (UIF 2) affects the counterfeit detection (UIF 3) has been object of study (Van der Horst et al., 2016). A qualitative study to preferences for, and confidence in, public authenticity features of euro banknotes has been carried out (Van der Horst et al., 2017).

The reported studies mainly concern the results of the biannual polls by DNB since 1981. The methodology behind these investigations is described in "A Method for Measuring the Public's Appreciation and Knowledge of Banknotes" (De Heij, 2002a). Further details on sample size, reliability and accuracy have also been published (De Heij, 2006a; 2007; 2008a).
Figure 6.3 presents the key information; further statistical accountability is kept outside the scope of this study.
In 2015 DNB contracted another agency, keeping the setup of the questionnaire similar. This transition was smooth; trends could be continued without any corrections.

This chapter reports on measurements carried out on several user functions of the Upid-Model. The measurements on UIFs are reported first: recognising value (section 6.2), handling (section 6.3), checking authenticity (section 6.4) and receiving the communication message (section 6.5). These measurements are followed by the measurements carried out on UXFs: experiencing identity (section 6.6), judging aesthetics (section 6.7), keeping confidence (section 6.8) and requiring sustainability (section 6.9). No measurements are available on linking banknotes to information technology from the users' perspective (UXF 6).
This chapter concludes with an answer to the research question, whether the Model for Use-centered Design of Payment Instruments is an appropriate framework to organise the measurements from the users' perspective (section 6.10).

LONGITUDINAL MEASUREMENTS			
User Functions of Banknotes		**Period**	**Periodic measurements**
UIF	1. Recognising value	1983 - 2017	Recollection of denominations
		1983 - 2017	Knowledge of image elements
		1983 - 2017	Knowledge of text elements
	2. Handling	2002 - 2017	Cleanness of banknotes in circulation
	3. Checking authenticity	1983 - 2017	Knowledge of authenticity features
		1983 - 2017	Average knowledge of authenticity features
		1983 - 2017	People who cannot recall a single feature
		2007 - 2017	Retailers checking banknotes
	4. Receiving com. message	1983 - 2017 1993 - 2017 2002 - 2017	Recall of name giving Recall of watermark images Recall of communication messages of euro
UXF	1. Experiencing identity	1983-2017	Best recalled design elements
	2. Judging aesthetics	1981 - 1993	Full life of NLG 100/Snipe (1981-1993)
		2002 - 2013	Full life of EUR 5 (2002-2013)
		2002 - 2015	Full life of EUR 10 (2002-2015)
		2002-2017	Full life of EUR 20 (2002-2017)
		1981 - 2017	Range of aesthetic scores
	3. Keeping confidence	2005 - 2017	Trust in banknotes.
	4. Reacting on main image	-	-
	5. Expecting sustainability	-	-
	6. Linking to IT	-	-
TUF	Total Usability Score (UIFs + UXFs)	-	-

Figure 6.1
Overview of longitudinal measurements on user functions of banknotes.

SINGLE EXAMINATIONS			
User Functions of Banknotes		**Year**	**Single examinations**
UIF	1. Recognising value	2009	Spontaneous awareness of pictures on NLG
		2009	Switching main images on euro banknotes
		2017	EUR 500 discontinued
	2. Handling	2009	Dimensions of euro banknotes
	3. Checking authenticity	1988	Effectiveness of marks for the blind
		2009	Relative importance of public authenticity features
		2013, 2015	Public attitude towards an authenticity self-check
		2015	Effect of new introduced features
		2016	Qualitative study to public auth. features euro
	4. Receiving com. message	2015	Recall of the image of "Europa" (the Greek myth)
UXF	1. Experiencing identity	2009	Design elements contributing to European identity
		2011	Suggestions for typical European characteristics
	2. Judging aesthetics	1981	Appreciation of banknotes in circulation
	3. Keeping confidence	2015	Halo-effect
		2016	Qualitative study to public auth. features euro
	4. Reacting on main image	2007	Suggestions for main image euro
	5. Expecting sustainability	2015	Attitude of the Dutch towards fair trade cotton
	6. Linking to IT	-	-
TUF	Total Usability Score (UIFs + UXFs)	2013	Usability score UIFs

Figure 6.2
Overview of the single examinations on user functions of banknotes.

6.2 Measurements of recognising value (UIF 1)

The first user function to be reported is recognising value (UIF 1). It starts with the presentation of the available measurements on the perception of design elements supporting value recognition for normal sighted (subsection 6.2.1), followed by the report of measurements carried out on the determination of the banknote's value by the visually impaired (subsection 6.2.2).

6.2.1 Design elements supporting value recognition

Gulden and euro banknote designs can be compared to each other by their *anchor note* (subsection 2.10.3), respectively the NLG 100/Snipe (1981) and the EUR 50/Renaissance (2002). The anchor note is the reference design, which is always part of the poll. The other note is a banknote design of special interest, usually the latest model issued.
Design elements of a banknote are split in *image elements* and *text elements* (De Heij, 2002a). Which design elements people recall of the gulden (1989) and the euro (2015) is shown in respectively figure 6.4 and 6.5. Over the years, the biannual polls delivered similar results and therefore these two tables are representative. In case of the NLG 100/Snipe, the best recalled design elements are snipe (68 %), numeral (60 %) and brown colours (43 %). These three design elements correspond to three of the four design elements contributing to value recognition; not mentioned by the Dutch are the banknote sizes. Two of these design elements are also in the top of the recalled design elements of the euro 50, the numeral (75 %) and the colours (orange by 35 % and brown by 27 %).
A specific pictorial element of a banknote is the main image, often a portrait and on modern banknotes also flora, fauna and buildings. What type of images are recalled best?

The main image of the euro 50 is recalled as “a part of a building” by 11 % (2015) and stays behind “snipe”, which is recalled by 68 % (1989). Only a few respondents can be more specific on the euro; the bridge on the reverse is mentioned more frequently (6%) than the arch/door on the front (4%, just outside the top 10) or the window on the front (1 %).
The recollection of the portrait of Dutch painter Frans Hals (~1580-1666) on the NLG 10 is reported in a separate study (De Heij, 2002a). The name of Frans Hals is printed close to the displayed portrait. Furthermore, the 10 gulden was an intensively used denomination, at the time of measuring, 1997, it had been in circulation for 27 years. Still, just 14 % of the public could tell the name of Frans Hals.
The era of the gulden banknotes ended in 2002 with a mix of two series and included images of a flower, building and abstract images. In 2009, this situation triggered a single examination on the recollection of main images on banknotes, reported in figure 6.6 (De Heij, 2010a).
Summarizing, measurements on the main image support the assumption that, within a series, people recall images taken from different categories better then images taken from one category.

STATISTICAL PRINCIPLES BIANNUAL POLLS BY DNB		
Research variable	**Specification**	**Remarks**
1. Sample size (n)	2,000 (1981-2003)	As the findings were over the years quite similar the sample size was reduced.
	1,500 (2005, 2007)	
	1,000 (2009 – 2017)	
2. Method	All citizens above 18 years	The “general public”.
3. Interviews by	Phone	Response in 2017: about 12 %. In order to report a representative sample of the Dutch population, corrections are made for age, gender, region and education.
4. Reliability	Around 95 %	Independent of the sample size. The accuracy margin of the answers depends on the sample size.
5. Accuracy (margin)	+/- 1.7 % (n = 2,000)	The accuracy depends on the sample size and on the number of interviewees that gave an answer to the question.
	+/- 1.9 % (n = 1,500)	
	+/- 2.4 % (n = 1,000)	
	+/- 4.3 % (n = 300)	
6. Sample period	February	4 weeks in February, each week about 25 % of the sample size
7. Frequency	Every 2 years	In odd years. In 2002 there was an additional poll held because of the introduction of the euro.
8. First measurement	1981	In 1981, only appreciation; since 1983, knowledge and appreciation.
9. Longitudinal	1981-1999 (NLG)	Covering clear trends and incidents.
	2002-2017 (EUR)	
10. Anchor note	NLG 100	Anchor note = banknote model that is each time part of the research as a reference.
	EUR 50	
11. Control questions	Yes	
12. Report after	6 weeks	
13. Costs	Around EUR 30,000	Including report.
14. Agency	1981-2013 TNS/NIPO 2013-2017 Motivaction	Setup of questionnaire was similar; trends could be continued without any correction.

Figure 6.3
Statistical principles biannual polls by DNB.

PICTORIAL AND TEXT ELEMENTS NLG 100				
Pictorial elements NLG 100 recalled by the public by heart	**1989 (%)**		**Text elements NLG 100 recalled by the public by heart**	**1989 (%)**
1. Snipe (Snip)	68		1. Figure 100/the number 100	60
2. Brown colours	43		2. Hundred gulden (Honderd gulden)	33
3. Bird	16		3. De Nederlandsche Bank	19
4. Head of a snipe on reverse	7		4. Banknote number(s)	18
5. Head of a snipe in watermark	6		5. Penalty code (Wetboek van strafrecht)	11

a) b)

Figure 6.4
Overview of pictorial (a) and text elements (b) of the NLG 100 banknote as mentioned most frequently from memory collection by the Dutch respondents in 1989 (partly published in Van Kasteren (1989); other figures reproduced from unpublished source: NIPO (1989). *Onderzoek bankbiljetten* (Research banknotes). NIPO. Amsterdam).

PICTORIAL AND TEXT ELEMENTS EUR 50				
Pictorial elements euro 50 recalled by the public by heart	**2015 (%)**		**Text elements euro 50 recalled by the public by heart**	**2015 (%)**
1. Orange/orange shades	35		1. Figure 50/the number 50	75
2. Brown/brown shades	27		2. The word EURO	31
3. Other colours	27		3. Banknote number(s)	14
4. (part of) building/historical building	11		4. Euro in Greek, ΕΥΡΩ	8
5. Hologram/foil stripe	7		5. Euro currency symbol €	6
6. Watermark/arch in watermark	7		6. Numeral 50 in watermark	5
7. Ring of stars	7		7. BCE ECB EZB EKT EKP	4
8. Bridge	6		8. Signature	4
9. European flag	4		9. Name: European Centrale Bank	2
10. Map of Europe	4		10. Year, date	2

a) b)

Figure 6.5
Overview of pictorial (a) and text elements (b) of the 50-euro banknote as mentioned most frequently from memory collection by the Dutch respondents in 2015. The numerals and the colours are by far the features best recalled (Randsdorp and Zondervan, 2015).

SPONTANEOUS AWARENESS OF IMAGES ON NLG BANKNOTES IN 2009	
Name mentioned	**Percentage (%)**
1. Snipe	25
2. Lighthouse	15
3. Sunflower	9
4. Other bird	5
5. A head of a person	5
6. Colour	4
7. Others	~ 15
8. Do not know	22

Figure 6.6
Seven years after circulation of guilder notes ended. The best recalled images are a snipe, followed by the lighthouse and sunflower.
The question was phrased as: 'Before the euro, we had guilder notes in our country. Which guilder banknote do you recall best? In other words, which one pops up in your mind?'

PERCEIVED DIFFERENCES BETWEEN TWO SERIES OF EURO BANKNOTES			
		Europa Series	
		Euro 5 and 10	Euro 10 and 20
		2015 (%)	2017 (%)
1.	Colours have changed	53	36
2.	Looks more modern	9	13
3.	Numerals are clearer	4	6
4.	Foil at the right side has changed	1	3
5.	(Parallel) lines along the sides	1	3
6.	Woman in watermark, portrait of Europa	1	2
6.	Look-through window/hole in foil	n.a.	2
7.	More round shapes	1	2
8.	A green numeral	1	1
9.	Woman in foil, portrait of Europa	0	1
10.	Other, namely	46	31
11.	Don't know	19	39

Figure 6.7
Knowledge of the differences between the two series of euro banknotes, the first series (ES1) named Ages and Styles of Europe and the second series (ES2) named Europa Series (Randsdorp and Zondervan, 2015; Klöne and Zondervan, 2017).
(An upgrade euro 50 banknote was issued in April 2017, after the 2017 poll.)

In 2013, the first model of the new Europa Series was introduced, the euro 5, followed by the euro 10 (2014) and the euro 20 (2015). In 2015 and 2017, the Dutch were asked about the differences between the two series (figure 6.7). The most reported difference between the old and the new euro designs is the change of colours. People also noticed the larger numerals, both changes on UIF 1. Newly introduced authenticity features (UIF 3) are less well known. The introduction of a portrait of Europa does not come across; neither in the watermark, nor in the holographic foil.

6.2.2 Measurements on the visually impaired

The visually impaired are divided in three user subgroups (subsection 3.2.5). For each subgroup measurements are available on value recognition. Measurements on the perception of the colour blind are reported first (topic 1), followed by measurements relevant to the poor sighted (topic 2) and the blind (topic 3).

1. Measuring the perception of colour blind

How colour blind persons perceive the colours of a banknote design can be measured using a colour blindness simulator (subsection 3.2.5). Images of euro banknotes were produced with such a simulator by Blind Color (studies reported in De Heij, 2009). To compare different banknote models with each other, the polychrome banknotes must be transformed into a monochrome banknote by the "Dominant Colour Method" or *DoCol Method*. The advantage of this method is that a small homogenous test sample (10 mm x 10 mm) can be used for colorimetric measurements. This sample can be brought into a colour space, like an a*,b*-chromaticity diagram. For a set of emergency banknotes (euro 20, 50 and 100), the so-called "6 Month Project", a colour blindness evaluation test was carried out in 2005; images of the euro banknotes were compared to the redesigns of the 6 Month Project. The test was repeated in 2008 for another set of upgraded euro designs, the "Two Years Project" (euro 20, 50 and 100).
The outcome of these two studies is that the colour-scheme of the circulating euro banknotes serves the colour blind best. Measurements on the perception of these two emergency series by the colour blind showed that these designs would not have been an improvement. Although the colour blind distinguish sufficient differences between the denominations, the colours of the first series of euro notes can be improved, especially for the euro 10, which should be more magenta, and the euro 100, which design should receive a brighter green.
The new euro designs, part of the Europa Series, have not been tested on how the colour blind would perceive these new banknotes.

2. Measurements of design elements for the poor sighted

The Print Contrast Ratio (PCR) is one of the relevant measurements on readability (subsection 3.2.2). The PCR of the CAD 10 (figure 3.7a) is 78 % (Spencer and Dupuis, 2007), a little higher than the 72.2 % reported in another study, where the CAD 10 received the highest score of a range of numerals measured (De Heij, 2009). Numerals on the euro 5 (figure 2.5a. on the left) and the USD 5 (figure 3.6c) have a similar height of 26 mm, but the PCR's are respectively 17.6 % and 52 % and therefore, the numeral on the 5 dollar is better readable than the numeral on the 5 euro.

3. Measurements of design elements for the blind

Marks for the blind on Dutch banknotes have been introduced in subsection 3.2.5. Twenty years after their introduction, the usage performance of these marks was object of study among 40 blind participants. The main conclusion was that the marks were not helpful (Koeze, 1990; Wertheim, 1990). Almost half of the blind participants said they never made use of the marks. Especially on used banknotes, the marks proved to be barely tangible. The study was made public and was the first to appear regarding this issue.

In the early years of the new millennium, a publication appeared on the effectiveness of "Tactile Features for the Blind" in Canadian banknotes (Lederman and Hamilton, 2002). The marks are constructed with raised dots, which received during production a height of 110 µm, while the height of the Dutch marks was about 60 µm. Six dots are grouped together to one *texture symbol*, which is the basis of a codification system for five denominations, each receiving a unique configuration. Each texture symbol consists of six raised dots. The proportion of correct responses never fell below 0.97; the mean response time per banknote takes on average 12.6 s., which is quite long.

6.3 Measurements of handling (UIF 2)

This section reports on measurements on handling banknotes. First reported are measurements carried out on taking a banknote (subsection 6.3.1), followed by measurements on neatness of euro banknotes (subsection 6.3.2).

6.3.1 Taking a banknote

Two different types of studies report on user preferences for taking a banknote, respectively where people touch a banknote and which size suits best.
Where people take a banknote has been studied by Lingnau et al. (2007), a study ordered by the ECB and reported by De Heij (2009). The results are shown in figure 6.8. The conclusion of this study is that people take banknotes on the centre of the short edges, telling that tactile patterns should be in these areas. Furthermore, as fingers will cover these areas, other types of public features should not be positioned here.

Public preferences have been collected on sizes of euro banknotes and the results are reported in figure 6.9 (De Heij, 2009). The most welcomed dimensions are the sizes of the euro 10 (127 mm x 67 mm) and the euro 20 (133 mm x 72 mm). The Dutch judge the euro 5 as too small. Another study confirmed this finding, reporting that 21 % of the Dutch respondents consider the euro 5 too small (De Nederlandsche Bank, 2007).
A study among elderly in Germany confirmed the public preference for the format of the euro 20: "Regardless of their vision, 52 % of the elderly people preferred the size dimensions of the Euro 20." (Müller, 2011).

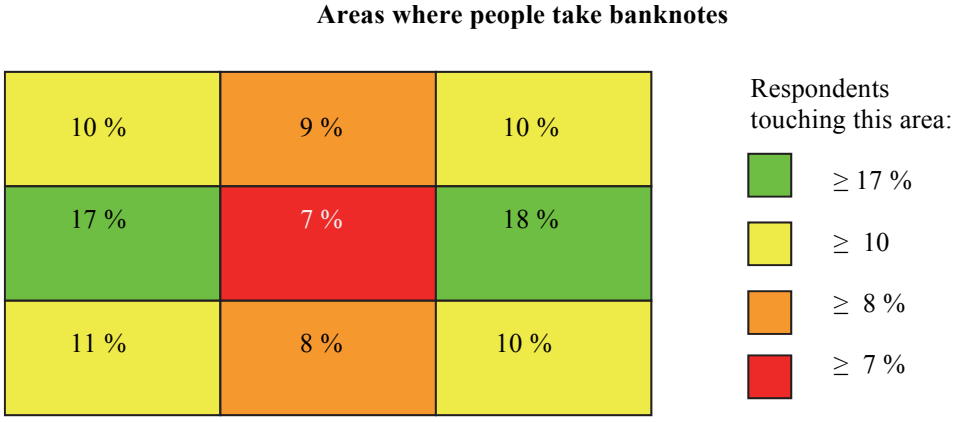


Figure 6.8
Areas where people's fingers touch the front of a 50 euro banknote.

PUBLIC OPINION ON THE BANKNOTE SIZES				
Euro denomination	**Answer categories**			
	Too small (%)	Correct (%)	Too large (%)	Do not know (%)
5	25	73	1	1
10	3	94	2	1
20	1	92	6	1
50	1	76	21	2
100	1	44	23	32
200	1	28	23	48
500	1	26	21	51

Figure 6.9
Overview of the public opinion in the Netherlands in 2009 on the banknote sizes of euro denominations.

6.3.2 Neatness of euro banknotes

In 2003, for the first time, the questionnaire on the biannual poll on knowledge and appreciation of banknotes included questions on the neatness of the euro banknotes circulating in the Netherlands. Neatness is comprised of multiple properties, such as dirt, creases, tears and folded corners (De Heij, 2006a). The results are presented in figure 6.10.
The first conclusion is that the Dutch judge the euro banknotes in circulation of good quality; neatness scores of all euro banknotes in the Netherlands are around 85 % clean. Most respondents judge the notes as very clean. Over the years the opinion on the neatness of euro banknotes is constant, except for the euro 5. In the eyes of the users, the neatness of the 5 euro increased from 71 % (2003) to 55 % (2013) and when a new euro 5 was introduced in 2013. This effect started to fade out in 2017.
What the Dutch find an acceptable quality of circulated banknotes has been studied (Van der Horst et al., 2011).
Banknotes with a folded corner (dog ear) coming out of an ATM are accepted by the Dutch, is the most remarkable conclusion. Within the Euro Area, quality sorting standards are harmonised and do not allow dog ears. Van der Horst reported that if dog ears would be allowed, DNB could recirculate sorted banknotes more often, saving about 30 % of all banknotes being destroyed. Based on the reported measurements, the conclusion is that sorting standards are set too high and can be reduced.

Since 2008, the central bank of Mexico keeps track of the quality of banknotes in circulation (Banco de México, 2015). Like in the Netherlands, the lowest Mexican denomination is perceived as the most worn. The lowest denomination in Mexico is the MXP 20, scoring 6.4 for quality on a scale from 1 to 10 in 2014, while the highest denomination received a score of 8.6 (MXP 1,000). The average quality in that year was 7.8.

To support an authenticity check, central bankers often argue that dirty, unfit banknotes should be taken out of circulation. This topic has been object of a joint study conducted by the De Nederlandsche Bank and the Bundesbank (Van der Horst et al., 2016). The general conclusion of this large-scale study among 261 cashiers and 250 consumers is that the condition of banknotes does not affect users' ability to spot counterfeits. On average, retailers detected approximately 88% of counterfeit banknotes and the public 79%. Retailers identified brand-new banknotes incorrectly as being a counterfeit, an example of a miss (figure 5.6).
The reported results match with a study by Jonker et al. (2006), reporting that, without practice, members of the public correctly identified 88% of counterfeit notes, within a stack of notes of circulation quality, while after training they scored as high as 96%.

6.4 Measurements of checking authenticity (UIF 3)

In 1981, DNB started with measuring the appreciation of banknotes, followed in 1983 with measurements on people's knowledge, focussing on the knowledge of authenticity features. Several publications report on the findings (De Heij 1986; 2002; 2007; 2008a; 2010a; 2012; 2016b). Studies have been carried out on the correlation between appreciation of a banknote and the public's knowledge on design elements and authenticity features (Koeze and De Heij, 1984; Den Butter and De Heij, 1985).

In short, the main findings are:

1) The average knowledge of correct authenticity features increased from 1 in 1983 to 2.3 in 2002, the year of the introduction of the euro. Since 2003 the Dutch recall about 2 features.
2) Over the years there is a large group, between 10 % and 20%, which cannot recall a single feature.
3) A substantial part of features recalled is not correct, about 5 % to 10 %. These features are divided in *incorrect* features (e.g. banknote numbers) and *partly incorrect* features (e.g. blind marks and type of paper).
4) People cannot recall more than four features (although there are exceptions).
5) People prefer one type of authenticity features over another. Features may score as high as 70 % (watermark), while others score as low as 2 % (see-through register).
6) People recall the watermark best, but cannot tell its image.
7) Features based on colour changes are not recalled.
8) Despite massive introduction campaigns, newly introduced features are barely recalled.
9) People would like to be able to check a banknote at one glance (instead of separate features); people would like to have all features on the front.

This section reports in more detail on public's preferences for authenticity features (subsection 6.4.1), followed by the public's knowledge on authenticity features (subsection 6.4.2), people's ability to detect counterfeits (subsection 6.4.3), the perceived number of counterfeits (subsection 6.4.4), the pbulic's attitude towards an authenticity self-check (subsection 6.4.5), retailers checking banknotes (subsection 6.4.6) and monitoring counterfeits (subsection 6.4.7).

6.4.1 Prefences of the public for authenticity features

Single examinations have contributed to a deeper understanding of the preferences of the public for authenticity features. The most relevant criterion to operate an authenticity self-check seems to be time (topic 1), followed by the public's preference for design concepts of public authenticity features (topic 2) and preferences for design concepts of authenticity features throughout a series (topic 3). Subsequently preferences of the public are reported for shiny foils over glossy inks (topic 4). Whether a feature should be designed as a separate element or as a band is another question answered (topic 5). Finally, the results are presented of a qualitative study to preferences of the public for public features on euro banknotes (topic 6).

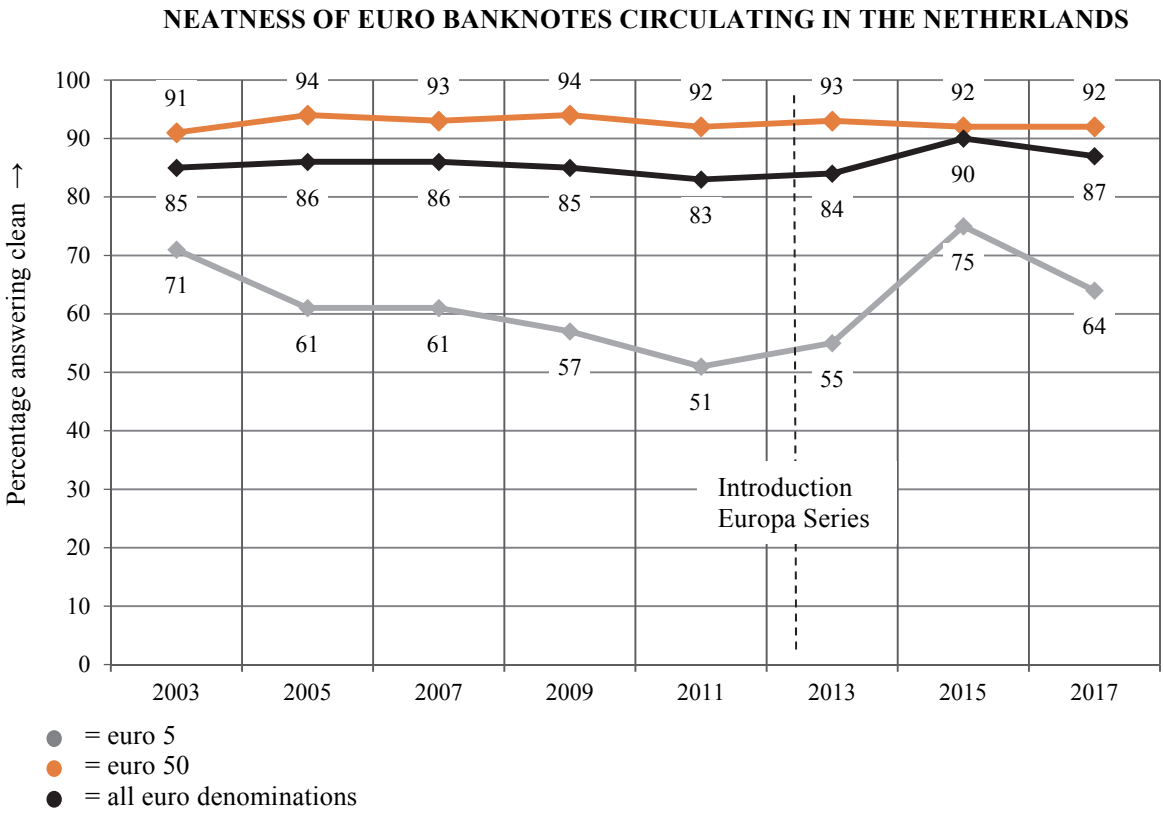


Figure 6.10
Neatness of euro banknotes according to the Dutch (Visser and Dijkers, 2013; Randsdorp and Zondervan, 2015; Klönen and Zondervan, 2017). Answers to the question: "How do you feel about the quality of banknotes? How do you feel it looks thinking of dirt, wrinkles, tears, writing, tape etcetera?"

TIME NEEDED TO CHECK A FEATURE		
Public security feature	**Reported checking time**	
	Central bank of Russia (2002)	Bank of Canada (2010)
	As accurate as possible, not worry about the time	As fast as possible, while optimizing accuracy
1. Watermark	8	4
2. Security thread	10.1	3.5
3. Holographic stripe	-	3
4. See-through register	-	5.5
5. Optically Variable Ink (OVI)	3.1	-
6. Latent image	18.4	-

Figure 6.11
Reported time to check a public authenticity feature based on two different instructions. In case of the RUB-banknotes people were asked to be as accurate as possible, not worrying about the time. In case of the CAD-banknotes respondents were asked to be as fast as possible while optimising accuracy.

1. Time spent on an authenticity self-check

Time seems to be the most relevant user requirement for an authentication self-check. Most likely, people will be prepared to spend more time on high value banknotes like a 100 dollar banknote, than on low denominations like a 5 dollar note, although supporting studies do not seem to be available. Studies have been carried out on the *inspection time of single features* and on the *inspection time of a complete banknote*. The inspection time of single features are summarized in figure 6.11, respectively based on a study on Russian ruble banknotes (Lyutov and Yurov, 2002) and a study on Canadian dollar banknotes (Balodis et al., 2010). These studies show that checking a single feature may take between 3 s up to 18.4 s. Second, quite different figures are reported for the authentication of similar features like a watermark and a security thread. These differences are explainable, as respondents received different instructions. In case of the Russian Ruble banknotes respondents were asked to be as accurate as possible, not worrying about the time, while the Canadian respondents were asked to be as fast as possible while optimising accuracy. Another difference is the presentation of the features, which were masked out in the Canadian experiment, while the rest of the banknote was covered. However, both studies indicate that the time threshold of an authenticity check of one authenticity feature is at least 3 s.
Another study reported on the inspection time of a complete banknote. When people explore a banknote, they spend more time at the front than at the reverse (Lingnau et al., 2007). In total respondents spent 5.3 s on verifying a banknote of 50 euro; the front was kept up for 3.5 s and people spent 1.8 s on the reverse.
Information on how much time people may spend on the authentication of a complete banknote may also be derived from studies done on the detection of counterfeits. Subjects may receive different time slots to judge whether a banknote is genuine or not, varying from 2 s (Jonker et al., 2006, Summers et al., 2008) up to 7 s (Klein et al., 2004). In another study (Raymond, 2017), a verification time of 4.1 s is reported for participants to authenticate a note within a set of fabricated genuine and counterfeited samples. An average authentication time of 6.3 s is reported when genuine and counterfeited banknotes should be selected from within a pile of banknotes, part of a large-scale study focusing on the influence of soil on the detection of counterfeits (Van der Horst et al., 2016). Experienced people, like retailers needed less time (5.0 s). Furthermore, it was reported that spending more than 10 s on a banknote did not lead to higher scores for judging correctly whether a banknote is a counterfeit or not.

Electronic means of payments may set a bench mark for the time spend on an authenticity check. A *contact less payment* by a debit card only takes 7 s, while a cash payment takes 14 s and a standard debit card payment using a PIN-code 17 s (Snoei et al., 2015).

Summarising, an authenticity check of a single public feature may take between 2 s and 3 s; a threshold to consider for the design requirements.

2. Public features should be on the front

Preferences of the public for design concepts of public features can be researched by *conjoint research*, a statistical technique offering properties or attributes to respondents in different sets (Green and Srinivasan, 1978). This technique determines how people value different combinations of feature properties and has been applied to the euro 50 banknote (model 2002). Six different attributes of public features were distinguished as listed in figure 6.12 (De Heij, 2010a). The location of the features received the highest relative importance, which suggests that all public features should be on the front. Second concern of the public is the number of features applied, followed by the type of images used. Appearance of public features is the least important attribute.
In the Europa Series, all promoted public features are positioned on the front, in line with the results of the conjoint research, and facilitating communication tools.

RELATIVE IMPORTANCE	
Attributes of public features (euro)	**Score in %**
1. Location	30
2. Number	23
3. Pictorial element (type of image)	18
4. Degree of complexity	13
5. Degree of conspicuousness	9
6. Appearance	6

Figure 6.12
Relative importance of the characteristics of the public authenticity features on euro banknotes.

3. Public preference for similar or different features within a series

Central banks tend to apply different authenticity features through a series of banknotes. This policy is usually driven by production costs, allowing more costly features on the higher denominations. An example are the euro banknotes (2002), split in low denominations (5, 10 and 20) and high (50, 100, 200 and 500). The difference between the low and high euro denominations are the foil feature and the special ink feature. The foil is either a band (low) or a patch (high) and the special ink is applied in respectively a band (low) and a numeral (high). Other central banks also offer their banknotes in two or three segments for reasons of cost benefits, like the Banco de México (Alegre Rabiela, 2016). The new Mexican G-series will be offered in three different substrates: polymer (MXP 50 and 100), high durability cotton substrate (MXP 200 and 500) and standard cotton substrate (MXP 1,000 and 2,000). The polymer and the cotton-based denominations will carry different public features. The variety of substrates will provide variation of the haptic properties throughout the series, and may affect the triggering of counterfeited banknotes by feel (subsection 5.2.2).

Dividing a series of banknotes in two or more parts is not in the interest of the banknote users and complicates public information tools (De Heij, 2006a; 2010a). As early as the preparatory phase of the "Euro 2002 Information Campaign" this distinction was found difficult to communicate (European Central Bank, 2001; 2004). For some features a common instruction could be made, while for two features separate instructions, including images, had to be prepared. Despite this effort, close to 70 % of the retailers remained unaware that the euro series of Ages and Styles is split in two groups with different authenticity features (De Heij, 2006a). Also to the public it was not clear. At least 9 % of the subjects believed there is a foil stripe on the 50 euro banknote, although the euro 50 has a patch. Asked for their preferences, one fourth of the respondents (25 %) would like to have similar authenticity features on all banknotes and the majority (75 %) does not have a preference, which is probably related to the wait-and-see attitude towards an authenticity self-check (subsection 6.4.5).

4. Preference of the public for a foil feature or a colour changing feature

Modern banknotes incorporate public authenticity features, like a foil feature and a colour changing feauture. Which of these two is preferred?
Most appealing to Canadians is a holographic stripe, while colour switching features were considered less attractive, as colour shifting effect is too difficult to see (Setlakwe and DiNunzio, 2004). The Bank of Canada therefore introduced a very wide foil stripe in their polymer notes, first issued in 2011. As reported in section 2.10, the first example of an authenticity feature introduced based on public input.

On the front of the Europa Series there is a foil feature and a colour changing feature. Like the Canadians, Europeans preferred the foil feature over the colour shifting feature (European Central Bank, 2013c). A large majority (71 %) could correctly locate the "portrait hologram", the image of Europa in the foil stripe, while only 27 % could locate the green numeral 5, a colour shifting feature. This finding is supported by a statement of Eagleman (2017), that on fake euro banknotes the colour didn't change, but were still accepted. A report on US dollar notes came to a similar conclusion, colour-shifting inks are rarely used by the public (National Research Council, 2007).
Other supporting evidence is provided by a survey among the Dutch. Just 2 % of the respondents recall the colour changing feature in the Europa Series, while 37 % recalls the hologram/silver foil, as will be elaborated on in subsection 6.4.2.
So the available evidence suggests that a foil feature is preferred over a colour changing feature.

5. Public preference for a continuous stripe or a separate element

Authenticity features on banknotes arrive in different variants, as introduced in topic 3. When the Dutch were asked which foil features - stripe or patch - they prefer, they opted for the silver coloured foil stripe (45 %) above the patch (23 %). This user preference matches with a higher awareness of a stripe (90 %) over a patch (59 %) (De Heij, 2006a).
Likewise, when the Dutch were asked for their preference for a gold shining band (low euro denominations) or a colour changing numeral (high euro denominations), the band is preferred (36 %) over the colour changing numerals (26 %). In this case these findings were not in line with their awareness, as the colour changing numerals (25 %) are recalled more often than the gold shining band (21 %).
The conclusion of this study is that people prefer a stripe or band over a patch.

6. Confidence and authenticity in features on euro banknotes

The Europa Series has introduced several new authenticity features for public use. These changes may affect the authenticity self-check (UIF 3) and the confidence in euro banknotes (UXF 3). By means of a qualitative survey the public's reaction in the Netherlands was investigated (Van der Horst et al., 2017). The study is based on 70 single face to face interviews. Respondents were offered a total of 48 cards with isolated authenticity features, partly genuine, partly counterfeited (figure 5.5). The main results are provided in figure 6.13.

CONFIDENCE AND AUTHENTICITY EURO			
Public authenticity feature		**Inspiring confidence UXF 3**	**Checking authenticity UIF 3**
		34 respondents	36 respondents
	Feature on	Score 1 to 10	d'
1. Holographic foil	euro 20 ES2	8.0	1.88
	euro 20 ES1	8.2	0.97
2. Raised ink	euro 20 ES1	6.0	1.07
	euro 20 ES2	6.0	0.75
3. Watermark	euro 20 ES1	6.1	0.78
	euro 20 ES2	5.8	0.47
4. Colour changing feature	euro 50 ES1	7.6	0.76
	euro 5 ES2	5.3	0.20

Figure 6.13
Overview of the results of a qualitative study to the public authenticity features on the first and second series of euro banknotes in 2016.

In terms of authentication, the foil on both euro series, respectively Ages and Styles of Europe (ES1) and the Europa Series (ES2) scored about equally well. The conclusion of this study is that the public features in the Europa Series are, when it comes to confidence and an authenticity self-check, quite like the ones in the first series. The holographic foil in the Europa Series scores better, while the colour changing feature receives a lower score. Respondents find it hard to tell the difference between genuine and counterfeit, mainly because of the multitude of features.

6.4.2 The public's knowledge of authenticity features

The biannual studies done in the Netherlands delivered a unique set of longitudinal data over the years 1983-2017, first on guilder banknotes (1983-2001), followed by euro banknotes (2002-2017). The average knowledge of *correct* spontaneously recalled public authenticity features doubled, from one in 1983 to two in 2017 as shown in figure 6.14. At the end of the gulden era, the introduction of the euro provided a boost, from an average of 1.7 in 1999 to 2.3 in 2002 (De Heij, 2006a). Since then, the average moves between 1.9 and 2.3 features (Klöne and Zondervan, 2017), above the average of the former guilder banknotes.

Differences are found across social classes. People belonging to the highest social class mentioned on average 3.6 features, while people of the lowest social class recalled on average 1.8 feature (Visser and Dijkers, 2013). These findings match with a study by Van der Horst et al. (2016), reporting that older people have more difficulty spotting counterfeit notes than younger people. Older people also check fewer authenticity features. Indeed, the attitude of elderly towards an authenticity self-check is quite passive, as will be elaborated on in subsection 6.4.5.
The studies in the Netherlands showed that knowledge of authenticity features correlate with gender, wealth and age. Men are able to name more authenticity features than women, and people in the 18-35 age bracket memorise on average more than those aged 55-plus. However, as introduced in subsection 3.4.5, only a single person can recall more than four features, usually young and higher educated men.

The finding that the Dutch recall on average about two public authenticity features is in line with findings reported for Japan and Mexico. The scores reported for the Netherlands and Japan are compared with each other for the period 2009-2015 in figure 6.15 and are quite similar. In Mexico people recall on average two or more authenticity features (Banco de México, 2015).

People may provide an answer to the question of what authenticity features they know, but this does not imply that the answer given is correct. Figure 6.14 provides two lines, a green and orange line, representing respectively the categories ‘correct answers’ and ‘answers including wrong and partly wrong answers’. Over the years 1983-2017 the gap between these two categories has narrowed, owing to the decrease of ‘partially wrong answers’. This reduction is explained as follows. In the period 1983-2002 improvements have been made for both the design and the communication of public features. In these years, the Dutch central bank introduced leaflets and posters. Second, the public features of the euro are not the same as for the gulden. At the time of the gulden the paper was not an official public feature, as the ‘feel of the paper’ cannot be explained unambiguously; what exactly should people feel? However, the feel of the banknote is often a first trigger to a deviant banknote (subsection 5.2.2) and the paper became an official public authenticity feature in the communication tools of euro banknotes - it should be crisp and firm - and is often promoted in combination with ‘raised print’, as introduced in subsection 3.4.4.
The group of incorrect features is small. The signature is the most frequently recalled, while other incorrect features are mentioned only incidentally, like register marks. Partly incorrect features are marks for the blind and the banknote number. The marks for the blind are part of the tactility of the banknote, which is present in several regions. One cannot tell if a banknote is real by its number, as a number is easily reproduced.

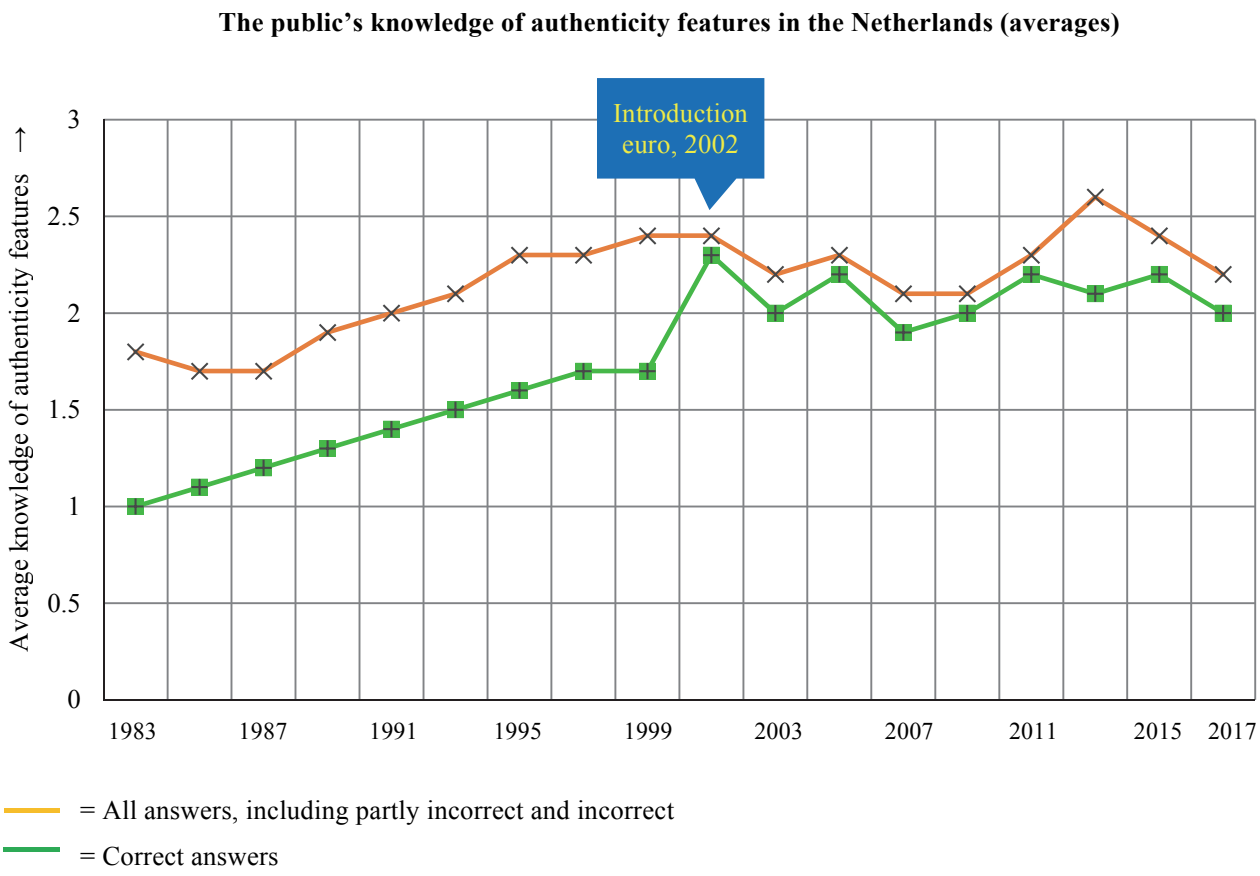


Figure 6.14
Longitudinal data of the average of the public's knowledge of authenticity features in the Netherlands over the years 1983-2017 (De Heij, 2006a; Klöne and Zondervan, 2017). The average number of correctly named security features increased from 1.0 in 1983 to 2.3 in 2002 at the time of the introduction of the euro. Since 2002 the average knowledge of correctly recalled authenticity features of the euro is between 1.9 and 2.3.

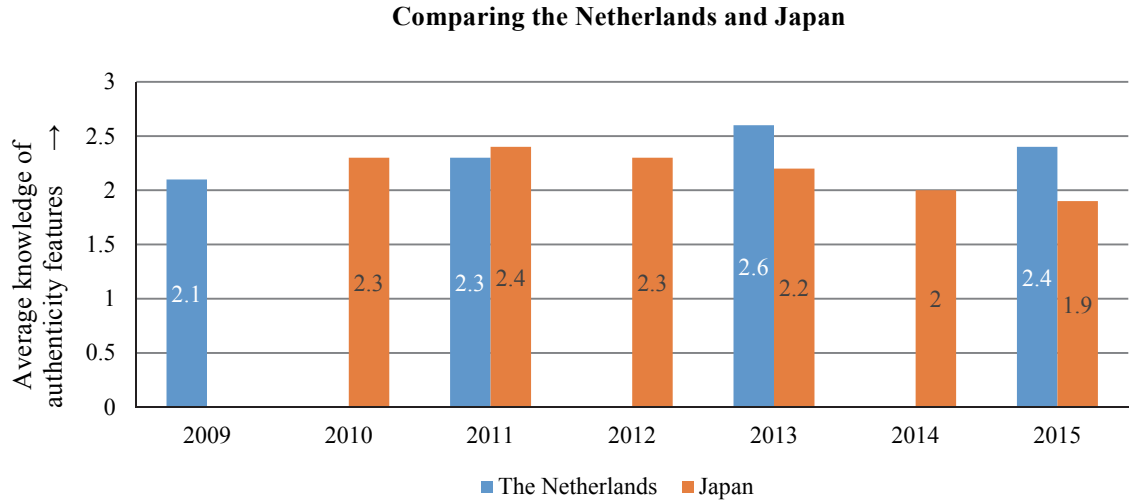


Figure 6.15
Comparing the total average number of authenticity features recalled in the Netherlands (Randsdorp and Zondervan, 2015 and Japan (Ministry of Finance of Japan, 2012; 2015).

KNOWLEDGE OF AUTHENTICITY FEATURES OF EURO BANKNOTES IN NL									
Year	**2002**	**2003**	**2005**	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**
Number of respondents	2,002	2,015	1,501	1,506	1,058	1,003	1,020	1,010	1,002
Watermark (in %)	70	65	68	65	76	75	79	71	68
Hologram/silver foil (in %)	61	52	49	43	55	49	57	37	37
Look-through window/hole in foil	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	2
Security thread (in %)	31	13	12	14	15	16	13	14	18
Special ink: glossy stripe (in %)	5	3	3	4	2	2	3	5	4
Special ink: colour changing ink (in %)	5	3	4	4	3	3	3	3	4
Special ink: rolling bar (Euro series 2)*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	2
See-through register (in %)	7	5	5	5	9	6	8	4	2
Raised ink, relief (in %)	7	5	9	5	8	8	14	12	4
Type of paper (in %)	7	8	10	7	14	11	17	12	16
Micro-text (in %)	3	4	4	4	6	6	4	2	2
Ultra Violet (UV), total (in %)	11	16	23	18	27	16	16	17	14
- dull paper (in %)	*1*	*2*	*5*	*4*	*3*	*2*	*3*	*3*	*3*
- fluorescent fibres (red, blue, green) (in %)	*5*	*9*	*12*	*7*	*16*	*8*	*8*	*8*	*7*
- ink brightens up (front: flag, signature) (in %)	*3*	*3*	*3*	*3*	*5*	*3*	*2*	*6*	*3*
- ink brightens up (reverse: bridge, map) (in %)	*2*	*2*	*3*	*2*	*3*	*3*	*3*	-	*1*
- hold under UV light, not specified (in %)	-	*1*	*3*	*2*	-	-	-	-	*1*
Infra Red (IR) (in %)	2	3	5	3	5	4	9	4	3
Average number of correct auth. Features	2.3	2.0	2.2	1.9	2.0	2.2	2.1	2.2	2.0
PARTLY INCORRECT									
Signs for the blind (in %)	10	11	12	11	18	14	14	11	16
Banknote numbers (in %)	1	2	3	-	5	5	5	7	6
Cannot be copied (in %)	2	-	-	-	1	-	-	-	-
Effect special pen (in %)	-	-	1	-	2	1	2	2	4
INCORRECT									
Signature (in %)	1	-	-	-	1	1	1	1	1
Average number of correct, partly correct and incorrect authenticity features	2.4	2.2	2.3	2.1	2.1	2.3	2.6	2.4	2.2
DON'T KNOW ANY									
Cannot recall any auth. feature (in %)	11	18	15	19	7	11	6	13	14

n.a. = not applicable
*) A colour changing ink, from blue to green, showing a movement effect. Promoted as the "esmerald number".

= Correct knowledge of authenticity features
= Knowledge including incorrect features

Figure 6.16
Knowledge of the authenticity features of euro banknotes in the Netherlands over the years 2002-2017. The table is prepared by De Heij on the occasion of the 2017 measurements, reported by Klöne and Zondervan (2017). All measurements are carried out in order of DNB by TNS NIPO, except for 2015 and 2017 when the measurements were carried out by Motivaction.

On average, the Dutch know two authenticity features and the ones which are recalled best are provided in figure 6.16. Over the decades the watermark is the most frequently recalled feature, oscillating around a score of 70 %. The second position is for the holographic foil stripe, although spontaneous recall of this feature declined from 61 % in 2002 to 37 % in 2017. This is remarkable, as the foil is the best performing public feature within an authenticity self-check and also contributes, more than other public features, to experiencing confidence (subsection 6.4.1).

Figure 6.16 revealed that there is a large group which cannot tell any feature. Figur 6.17 provides a graph representing the period 1983-2017 and displaying the average number of Dutch respondents unable to tell any feature, which fell from 20% in 1983 to 14% in 2017. The ECB reported that around 30 % of the people cannot recall one single security feature; in some Euro Area countries, this holds for even more than 50 % of the population (European Central Bank, 2004a). Accoriding to a separate measurent in Spain, almost 20 % of the population cannot tell a single feature (Negueruela and Fernández, 2008).
Outside the Euro Area, similar findings have been reported. In the United States, 15 % of the subjects cannot tell any feature (De Heij et al., 2003). For New Zealand this figure is 18 % (Reserve Bank of New Zealand, 2011a) and in Japan the mean value is 21.7 %, over a five-year period, running from 2010 to 2015 (Ministry of Finance of Japan, 2012; 2015). Even higher scores are reported for Romania, where 24 % of the public have no idea of any authenticity feature (reported in: De Heij, 2007). The Bank of Canada reported that 26 % of the public was not aware of any authenticity feature on a just issued banknote (Setlakwe and DiNunzio, 2004).

Recalling a feature is unprompted knowledge, which does not imply that respondents know details about the specific feature recalled. The watermark is the best recalled feature in the Netherlands, mentioned by about 70 % of the respondents (figure 6.16). However, when asked for its image, people are unable to provide an answer; the most frequent recalled features are listed in figure 6.18 (De Heij, 2002; 2008; 2010). These findings demonstrate that people are unable to tell what the watermark image represents. The few subjects coming up with an answer, use a wide variety of words, calling it an arch, window, Greek building, church, chapel, balcony, niche, alcove or altar. Similar findings are reported for the other public features in euro banknotes, like raised ink, the holographic foil and colour changing features (Van der Horst et al., 2017).
Concluding, people seem to have a qualitative understanding of authenticity features and not a quantitative; people do not seem to know which specifications to check for within an authenticity feature.

Knowledge about public features of banknotes circulating in the Netherlands is actively promoted since 1981. At first only by printed communication tools, like leaflets and posters, later also by electronic tools (subsection 3.5.2). In figure 6.19, the promoted public features are compared to the public's knowledge for the year 2017. This table shows a substantial difference between the score for the best-known feature, the watermark (71 %), and the least known feature, the colour shifting features (3 %).
These findings confirm the results of a qualitative study (Van der Horst et al., 2017), reported in subsection 6.4.1, topic 6, reporting that the colour changing ink, introduced in the Europa Series in 2013, has not been picked up by the Dutch. The unprompted knowledge of the rolling bar, the esmerald number, is 2 % (figure 6.16). In a qualitative study, this feature received a lower score than the feature it replaced, the Optically Variable Ink (OVI) on the reverse of the high euro denominations of the first series, respectively d' = 0.20 for the rolling bar and d' = 0.76 for the OVI (figure 6.13). Furthermore, the rolling bar did not contribute to confidence in euro banknotes.
However, the situation may be different in other countries. In Spain, the watermark in the euro banknotes is ranked fourth (Pérez et al., 2014), while in the Netherlands, using the same euro banknotes, the watermark is ranked first. Following this study, the most frequently verified authenticity features in Spain are reported to be paper, security thread and raised print.
Mexicans are most aware of a '3D security thread' (Banco de México, 2014).

What triggers people to do an authenticity self-check? To arrive at an answer, respondents were invited to tell why they did an authenticity self-check (Visser and Dijkers, 2013). The results are provided in figure 6.20, telling that most respondents answered "out of curiosity or habit" (22 %), which are in fact two reasons, but they are not separately reported. The second largest response category, 19%, are respondents triggered by the different feel of the paper and/or the perception of banknotes looking too nice and/or looking too new.
Just 3% of the Dutch public did an authenticity self-check because they had heard about falsifications.

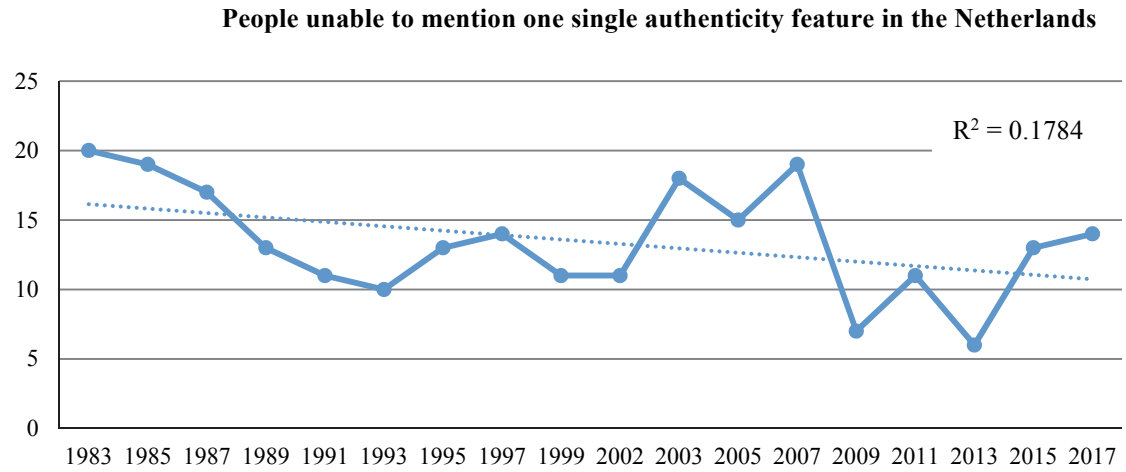


Figure 6.17
People unable to mention one single authenticity feature over the years 1983-2017. The R-squared value of the linear trendline is 0.1784 indicating that the trendline is not very reliable. The average number declines from 16 % in 1983 to 14 % in 2017.

KNOWLEDGE OF WATERMARKS		
Watermark image	**5 euro (in %)**	**50 euro (in %)**
Same picture as printed	2	1
Bridge	2	1
Gate, door	2	3
(Part of) building	1	2
Number 5/50	2	2
Animal	1	0
Others	2	2
Does not know	89	89

Figure 6.18
Knowledge of watermarks of euro banknotes in the Netherlands in 2013 (Visser and Dijkers, 2013).

PROMOTED PUBLIC AUTHENTICITY FEATURES				
Promoted public authenticity features	**Knowledge**	**NLG**	**EUR (ES 1)**	**EUR (ES 2)**
	Netherlands 2017	Period 1981 - 2002	Period 2002 - 2017	Period 2013-2017
1. Watermark	68 %	x	x	x
2. Hologram/foil	37 %	x*	x	x
3. Security thread	18 %		x	x
4. Type of paper	16 %		x	x
5. Raised ink, relief	4 %	x	x	x
6. Glossy gold stripe	4 %	x*	x	x
7. See-though register	2 %	x	x	
8. Colour changing ink (ES1)	4 %		x	
9. Micro-text	2 %	x		
10. Rolling bar (ES2)**	2 %			x
11. Hole in foil (transparent window)	2 %			

x = promoted public authenticity feature
*) A foil and a glossy ink were introduced on NLG-notes in 1992.
***)* A colour changing ink, from blue to green, showing a movement effect.

Figure 6.19
Overview of the promoted public authenticity features in the Netherlands during the guilder and the euro period. On the left the public knowledge of these features in the Netherlands (Klöne and Zondervan, 2017).

WHY AN AUTHENTICITY CHECK?	
Why did you do an authenticity check in the past five years?	**Netherlands 2013 (%)**
Out of curiosity or habit	22
Paper felt different, too nice, too new	19
Dirty, pale, wrinkled, damaged banknote	17
Part of my job	13
Circumstances: busy area, kind of person I received it from, doubt	9
Appearance of banknote	5
High-value banknote	3
Publications about circulation of falsifications	3
Heard/read about authenticity features	3
Colour seemed different	2

Figure 6.20
Why did you do an authenticity check in the past five years?

6.4.3 People's ability to detect counterfeits

The preceding subsections reported on preferences of people for specific authentication features (subsection 6.4.1) and on people's knowledge of such features (subsection 6.4.2). This subsection continues with measurements done on people's ability to detect counterfeits.
When it comes to test people on their ability to detect counterfeits, there are two situations. Genuine or a counterfeit notes can be presented one-by-one to an individual, a method applied by Klein et al. (2004). Persons may also be asked to sort a stack of banknotes into genuine and fake, a method applied by Van der Horst et al. (2016). Instead of banknotes, the method can also be applied to isolated public authenticity features as done by Firth and Balodis (2011) and by Van der Horst et al. (2017).
Figure 6.21 provides an overview of these studies introduced, following Raymond (2017). This overview is supplemented with d-prime scores for isolated features in euro banknotes (Van der Horst et al., 2017), reporting d' = 1.88 for the best public feature of all euro banknotes, being the foil on the euro 20 of the Europa Series.
The presented data shows that d-prime scores vary between 0.20 and 2.21 for different sets of genuine and mimicked banknotes.

6.4.4 Perception of the number of counterfeits

People may become aware of communication on falsifications (subsection 6.4.2), which may trigger them to do an authenticity self-check. The Dutch media report regularly about counterfeited banknotes, including twice a year because of the press release by the ECB on counterfeit statistics. However, measurments show that just 3% of the Dutch checked their banknotes during the past five years, because they had heard about falsifications. People do not seem to be triggered by the number of counterfeited banknotes. As people tend to overestimate the number of counterfeited banknotes, they may have a different view of reality (figure 6.22). The reported studies deliver different figures, exceeding the real number by magnitudes of 100 up to 10,000, far above the commonly held threshold of 0.005 % or 50 ppm (subsection 3.4.1).

6.4.5 Public attitude towards an authenticity self-check

In 2014, most Mexicans (60.2 %) check their banknotes (Banco de México, 2015). Unlike Mexicans, most of the Dutch respondents never check a banknote. This number increased from 52 % in 2013 to 65 % in 2017, as shown in figure 6.23 (Visser and Dijkers, 2013; Klöne and Zondervan, 2017). The fast majority (53 %) do not expect that their behaviour will change. For 13 % of the respondents is a banknote check part of their work. Most respondents do a self-check out of curiosity or habit (22 %). Furthermore, banknotes are easier accepted by people in lower social classes and respondents living in cities. Older people verify banknotes less often than others, reported in the Netherlands (Randsdorp and Zondervan, 2015) and also in Germany (Müller, 2011).

6.4.6 Retailers checking banknotes

Retailers receive more banknotes per day than a private person (subsection 1.3.1). Typically, they receive the high ATM denominations withdrawn by the public, like in the Netherlands the euro 20 and 50 (figure 6.24a). Counterfeiters target these two ATM denominations, and especially the euro 50 (figure 6.24b). Over the years this situation has not changed, as illustrated by figure 6.25.
Retailers are using more *Banknote Authentication Devices* (BADs) as shown in figure 6.26, an increase from 55 % (2007) to 80 % (2015). About 1/3 of the retailers (still) has UV-lamps, while about 2/3 have automatic devices (De Nederlandsche Bank, 2015a).
As automatic devices are increasing, a Dutch study delivered more insight in this development, especially at smaller retailers (Van Marwijk, 2016). A diversity of devices is reported and about 50 % of the retailers rely on two types of BADs.

The higher the denomination, the more attention the retailer pays to the notes. Small retailers check only about 20 % of the low denominations, the euro 5 and 10. The fast majority (83 %) checks all incoming euro 20 banknotes and in case of the euro 50 all most all (94 %) of these notes are checked. The higher the denominations, the less willing retailers are to accept them. Here too, retailers discriminate; the euro 100 is accepted by 89 % of the small retailers, the euro 200 by 56 % and the euro 500 by 44 %. If accepted, small retailers check higher denominations up to 100 %.

The Reserve Bank of New Zealand (2011b) also published on surveys among retailers. Almost 40 percent (39 %) retail respondents stated they check for counterfeits once a month or more. The transparent window in the New Zealand notes is by 72 % of the retailers identified as a security feature.

6.4.7 Monitoring counterfeits

A counterfeiter aims for mimicked banknotes, which will be accepted by the public or by a machine. To achieve this goal, a counterfeiter usually does not reproduce all authenticity features, phrased by Eagleman (2017) when examining a set of counterfeited euro banknotes as follows: “Many of the counterfeited notes had no security features at all”. Therefore, it is relevant to gain insights in the features the counterfeiters reproduce. Usually, a central bank keeps track of the number of counterfeits seized (subsection 3.4.1). Figure 6.27a presents the *average quantity* of mimicked euro banknotes registered in the Netherlands over the years 2008-2015. This graph shows that this number oscillates around 4,200 counterfeits per month. Insights in the quality of faked banknotes is provided by the Simple Method (subsection 3.4.1).

Figure 6.27b displays the *average quality* of mimicked euro banknotes over the years 2008-2015, retrieved from circulation in the Netherlands. On average this imitation quality turns out to be 5.9 points and its standard deviation is low, 0.3 points; counterfeiters imitate about 50 % of the quality of the features (to be published: De Heij, 2018).
Although the average quality of counterfeited euro banknotes is stable, counterfeiters do use the full range of zero to twelve points. In 2015, for the first time, one of the euro models received the maximum of 12 points.
Some counterfeits received just 1 point, while a zero score has not been registered. Figure 6.27c provides the *average weighted quality*, turning out to be 7.1 points, with a standard deviation of 0.3 points.
Counterfeiters focus on the features that people recall, so is assumed after analysing figure 6.28. In the top three of this list are watermark and foil, the two-best known public features (figure 6.16). Arguing along this line, the strongest public authenticity features are the gold shining band and the colour changing feature.

COUNTERFEIT DETECTION-PERFORMANCE REPORTED IN d'					
Study reported by	**Currency**	**Number of counterfeits (%)**	**Hits**	**Miss**	**d'**
Klein et al. (2004)	CAD	33 %	76 %	13 %	1.83 *
Van der Horst et al. (2016)	EUR	10 %	79 %	8 %	2.21
Jones and Raymond (2017)	GBP	4 %	70 %	10 %	1.38
Van der Horst et al. (2017)	EUR Foil Europa	75 %	59 %	5 %	1.88
	EUR Emerald number	75 %	32 %	25 %	0.20
Raymond (2017)	Fantasy	17 %	73 %	16 %	1.58

*) Not reported in Klein et al (2004); calculated by Raymond.

Figure 6.21
Overview of studies on the counterfeit detection-performance of several currencies in d' (for the group), based on Raymond (2017) and Van der Horst et al. (2017).

RECEIVING COUNTERFEITED BANKNOTES						
Study reported by	**Year**	**Area**	**User group**	**How**	**Past**	**Future**
De Heij (2006b)	2004	NL	Public	Estimated	-	30 % to 100 %
			Retailers	Estimated	-	0.5 % to 10 %
De Heij (2010)		Eurozone	Retailers	Estimated	49 %	-
Kosse (2010)	2010	NL	Public	Estimated	11 %	-
Visser and Dijkers (2013)	2013	NL	Public	Experience	6 %	-
				Estimated	< 10 %	15 %

Figure 6.22
Overview of studies on to the perception of receiving a counterfeited banknote.

AUTHENTICITY SELF-CHECK				
Answer categories		**2013**	**2015**	**2017**
1.	No, and I did not consider it	52 %	54 %	65 %
2.	No, but I did consider it	13 %	7 %	6 %
3.	Yes, once	5%	5 %	6 %
4.	Yes, 2 to 10 times	13 %	13 %	13 %
5.	Yes, more than 10 times	18 %	20 %	9 %

Figure 6.23

Answers to the question "Have you ever checked a euro banknote for authenticity in the past five years?" (Visser and Dijkers, 2013; Randsdorp and Zondervan, 2015; Klönen and Zondervan, 2017).

Distribution of counterfeits

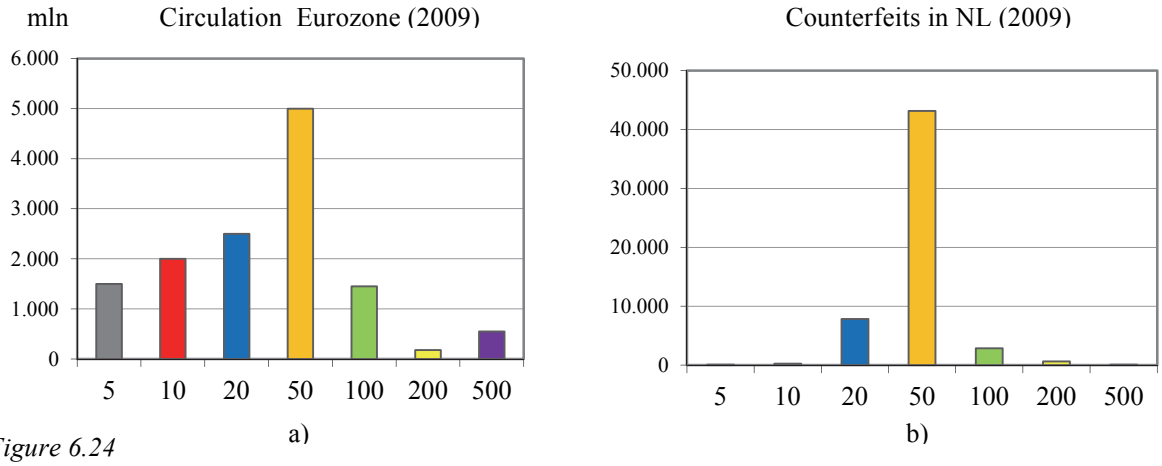


Figure 6.24
Two graphs representing respectively the circulation of euro denominations in the Eurozone and the counterfeited euro denominations in the Netherlands.
a) The number of euro denominations in millions issued per denomination within the Eurozone (European Central Bank, 2010b).
b) The euro 50 is the most frequently detected counterfeited banknote in the Netherlands (De Nederlandsche Bank, 2010b).

COUNTERFEITED EURO BANKNOTES				
	Netherlands			Worldwide
	Numbers	Share euro 20	Share euro 50	Numbers
2010	39,600	21 %	70 %	751,000
2011	29,700	27 %	63 %	606,000
2012	29,500	30 %	60 %	531,000
2013	37,700	23 %	69 %	670,000
2014	48,600	24 %	67 %	838,000
2015	68,200	30 %	59 %	899,000
2016	47,200	12 %	73 %	684,000

Figure 6.25
Statistics of the number of counterfeited euro banknotes in the Netherlands and worldwide over the years 2010-2016 (De Nederlandsche Bank, 2017b).

USE OF AUTHENTICITY DEVICES BY RETAILERS							
Authenticity device	Eurozone Average (%)		Netherlands (%)				
	2009	2015	2007	2009	2011	2015	2015*
Ultraviolet lamp	19	21	35	33	31	24	30
Infrared viewer	8	2	4	3	3	-	4
Automatic device	8	15	16	22	30	56	22
Do not use any tools	54	54	45	40	36	20	35

Figure 6.26
Use of authenticity devices by retailers in the Eurozone (TNS Opinion and Social, 2009) and the Netherlands (Hoofdbedrijfschap Detailhandel, 2008; 2010; 2012). As of 2012 figures are no longer available, as the branch organisation providing these figures has terminated these studies. The 2015-figures are reported by De Nederlandsche Bank (2015b). The 2015*-figures are reported by TNS Opinion (26 November 2015) to the ECB.

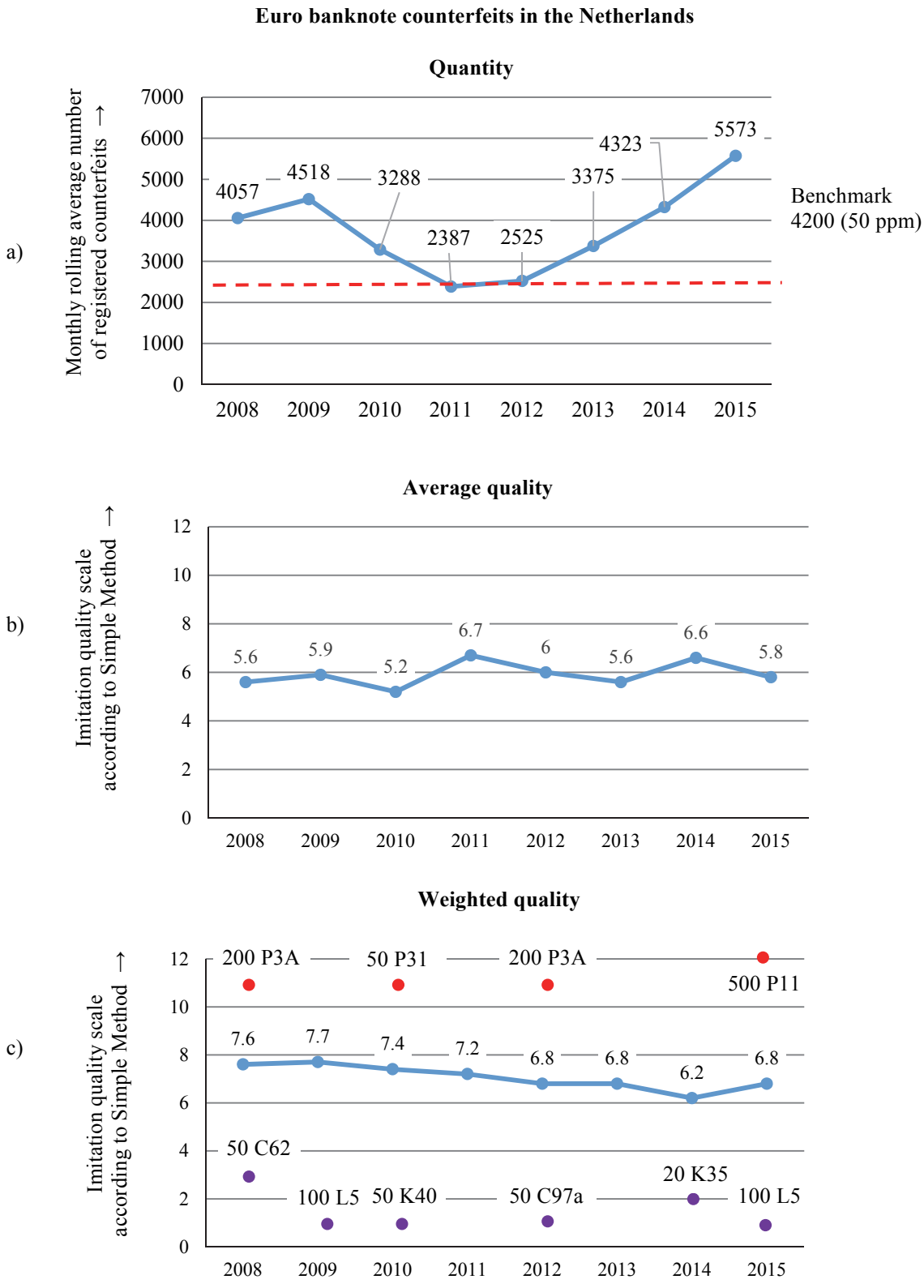


Figure 6.27
Quantitative and qualitative overview of counterfeited euro banknotes in the Netherlands over the years 2008-2015.
a) The rolling average of registered counterfeited euro banknotes each month by the National Analysis Centre (December values).
b) The average quality of the reproduction of public authenticity features in fake euro banknotes according to the Simple Method.
c) The average weighted quality of the reproduction of public authenticity features in fake euro banknotes. In red the counterfeit indicatives which received the highest score, in purple the lowest scores.

QUALITY OF COUNTERFEITED PUBLIC AUTHENTICITY FEATURES		
Public features	**Score (2 points max.)**	
	2008	**2015**
1. Foil	1.3	1.8
2. See-through register	1.2	1.4
3. Watermark	1.3	1.1
4. Security thread	1.0	0.8
5. Tactile effect gravure	0.6	0.5
6. Shiny or colour changing*	0.2	0.2
Total score (maximum 12)	5.6	5.9
Average score (maximum 2)	0.9	1.0
Retail features		
1. UV	0.9	1.1
2. IR	0.1	0.2

*) Gold shining band (euro 5, 10, 20) or
colour changing numeral (euro 50, 100, 200 and 500).

Figure 6.28
Quality of counterfeited public authenticity features in euro banknotes, based on the 10 most frequently received counterfeit types in the Netherlands, respectively in 2008 and 2015.

6.5 Measurements of receiving a communication message (UIF 4)

Euro banknotes include many themes (subsection 3.5.2), which is an explanation why most of the messages do not come through. Messages that relate to the euro as a means of payment are the most successful to come across. Figure 6.5 reveiled the spontaneous knowledge of pictorial and text elements of the euro 50 (2002) in 2015: the numeral (75 %), orange colours (35 %) and the word euro (31 %). The best recalled message is 'old buildings', recalled by 11 % of the Dutch.
When it comes to the public features, the measurements the response is also low. Four years after the introduction of the Europa Series 2 % of Dutch respondents recall that the watermark shows a "portrait of Europa and/or a woman" and her portrait in the foil is remembered by just 1 % (Klöne and Zondervan, 2017). The Dutch tend to associate the portrait of Europa to a 'little doll'.

6.6 Measurements of experiencing identity (UXF 1)

A dedicated study on the identity of euro banknotes was carried out in 2011 (De Heij, 2012). European identity is expressed by the word 'euro' (85 %), the map of Europe (85 %) and the currency symbol € (73 %). The flag of the European Union is ranked fourth (69 %).
Name symbolism is not appealing to the Dutch. A minority (17 %) perceives the text ΕΥΡΩ (Greek for EURO) as European and 12 % judges the abbreviations BCE ECB EZB EKT EKP as a European element.
Cash money is composed of coins and banknotes, and the perception of a coin identity can be different from the perception of a banknote identity, as is the case for the euro. To the Dutch the banknote identity is more important than the identity of a coin, respectively 61 % versus 45 % (figure 6.29).

However, euro coins (66 %) are perceived as being more European than euro banknotes (53 %), as reported in figure 6.30. Almost half of the respondents (47 %) is of the opinion that the euro banknotes do not reflect a European identity. This finding suggested a subsequent question on the appreciation of the design of the euro coins and banknotes. It turned out that both designs were valued about equal, a finding also reported in figure 6.29. Although euro coins are appreciated slightly higher (6.7) than euro banknotes (6.6), the difference is not significant. All respondents agree on this, as significant differences were not observed across gender, age, demographic region or social class.

IDENTITY OF EURO COINS AND BANKNOTES				
Year	**Question**	**Score**	**Euro coins**	**Euro banknotes**
2011	How important do you think it is for the appearance of euro banknotes and euro coins to reflect a European identity?	Very important and important	61 %	45 %
		Indifferent	30 %	35 %
		Unimportant, very unimportant	9 %	19 %
2013	What is your opinion on the design of the euro coins/banknotes? Please provide a score.	Scale 1 (very poor) to 10 (excellent)	6.7	6.6

Figure 6.29
Overview of the response on questions concerning identity of euro coins and banknotes (De Heij, 2012) and respondents' opinion on the design of respectively the euro coins and the euro banknotes (Visser and Dijkers, 2013). All measurements: Netherlands only.

EUROPEAN IDENTITY		
	Coins	**Banknotes**
European	66 %	53 %
Not European	33 %	47 %

Figure 6.30
Recorded answers to the question: 'To what extent do you think euro banknotes and euro coins have a European identity?' Answers were given on an interval scale with four units on European identity: very much, much, little and none. Netherlands only (De Heij, 2012).

6.7 Measurements of judging aesthetics (UXF 2)

Two sets of measurements are reported, the banknotes' appreciaton (subsection 6.7.1) and the emotions evoked by euro banknotes (subsection 6.7.2).

6.7.1 Appreciation

The appreciation of a banknote is measured on a 5-point interval scale, respectively very beautiful, beautiful, neither beautiful/neither ugly, ugly and very ugly. People tend to choose the answer in the centre (e.g. Klöne and Zondervan, 2017). This bias is corrected by application of the *dichotomous method,* a method emphasising the extremes, in case beautiful and ugly. The appreciation of a banknote (A, in %) is measured as follows (De Heij, 2004) :

$$A = \frac{\text{(total answers ('very nice' + 'fairly nice' + ('in between')/2))}}{\text{(total number of respondents minus 'absolutely don't know)}} \times 100\ \%$$

The appreciation of the NLG 100/Snipe is measured over its complete product lifecycle and is presented in figure 6.31 (De Heij, 2002a). Over the years the public's appreciation for this banknote model was steady, oscillating around 80 % 'beautiful'. It is the first time that such a complete appreciation curve has been prepared. In 2013, a similar graph was completed for the EUR 5/Classic (2002-2013), also part of figure 6.31. The Dutch qualified this model as 'ugly', on average the design scored below 50 %. The lowest score for the euro 5 is measured in 2009 and came out on 40 % beautiful, quite similar to the score of 41 % beautiful in 1991 for the first design by Drupsteen (figure 1.2b). Figure 6.32 provides these extreme scores and also presents the all time high, a score of 91 % beautiful for the NLG 250/Lighthouse (figure 1.1d), achieved in 1999.
When it comes to gender, a remarkable difference is found in the appreciation of the NLG 50/Sunflower and the NLG 250/Lighthouse (De Heij, 2008a). Women like the Sunflower more, while men appreciate the Lighthouse more. Women ranked the Sunflower first (30 %) against 16 % of the male, while men ranked the Lighthouse first (43 %) against 37 % of the women.

The appreciation of individual euro banknotes have been measured in the Netherlands from its introduction in 2002. Using these data, the average score can be calculated for all denominations, as presented in figure 6.33. Over the years, in increase is measured for the appreciation of the euro banknotes, except for the 5 euro, which declined from 54 % (2002) to 47 % (2011). When the first model of the Europa Series was introduced in 2013, a new euro 5, the appreciation for this denomination increased, from 47 % beautiful in 2011 to 74 % in 2013 (figure 6.34). However, two years later it fell back to a score of 62 % (Klöne and Zondervan, 2017). Why the score fell back has not be studied and may have several explanations. The primacy effect may have decreased and also the introduction of other new euro banknotes - an upgraded 10 in 2014 and an upgraded 20 in 2015 - might have been of influence. The re-designed euro 10 was also well received, increasing the score for this denomination from 65 % beautiful in 2013 also to 74 % in 2015. No increase was measured for the upgraded euro 20, the old and the new model received a similar score of 75 % beautiful, respectively in 2015 and 2017.

In the early years 2000, a similar question on banknote aesthetics was asked in three different countries, in Canada, the USA and the Netherlands, a unique exercise. The results are presented in figure 6.35. The conclusion is that people tend to judge their own banknotes as beautiful, while people from other countries may think otherwise. This tendency is consistent with cognitive dissonance.

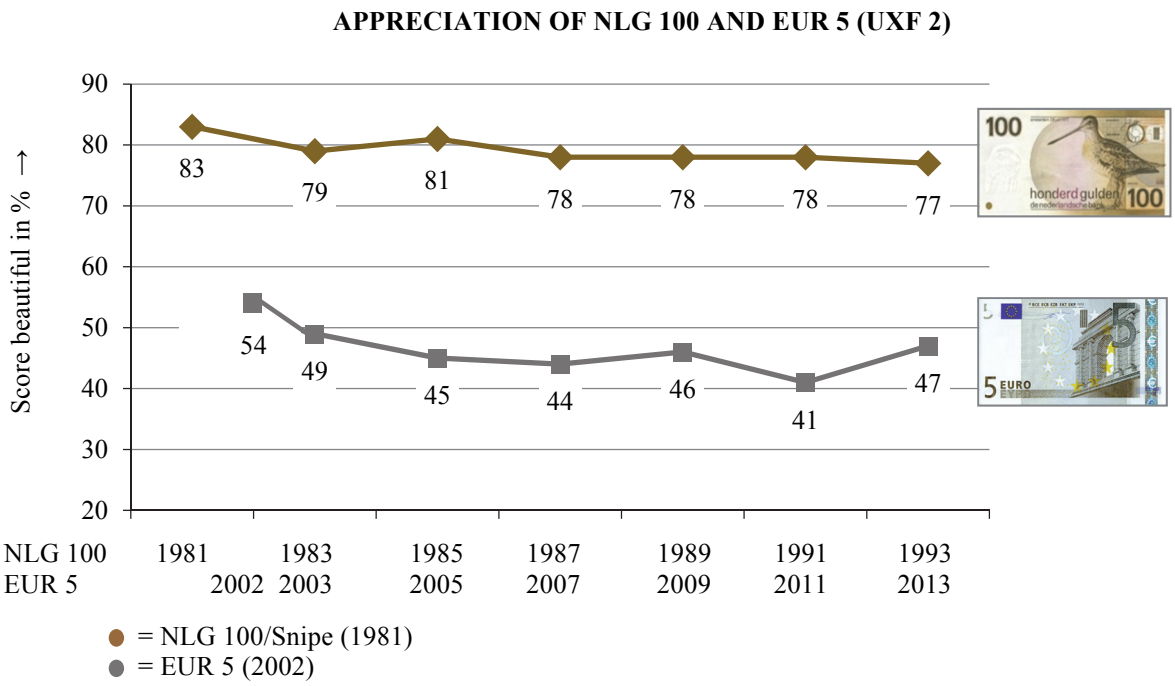


Figure 6.31
Complete appreciation curves for two different banknote models.
a) Stable beautiful score of the NLG 100/Snipe over its full lifecycle; from introduction (1981) to withdrawal (1993), an average score of 79 % beautiful.
b) Except for 2002, the EUR 5/Classic scored ugly over its full lifecycle; from introduction (2002) to withdrawal (2013), an average score of 47 % beautiful.

EXTREME SCORES 'BEAUTIFUL'			
Currency	**Period**	**Score beautiful**	
		Highest score	Lowest score
Gulden	1981 - 1999	91 % (1999) NLG 250/Lighthouse	41 % (1991) NLG 25/Robin
Euro	2002 - 2017	79 % (2007) EUR 500/Modern *	40 % (2009) EUR 5/Classic

Figure 6.32
Overview of the extreme scores 'beautiful' measured for guilder and euro banknotes (De Heij, 2002; De Heij, 2012; Visser and Dijkers, 2013; Randsdorp and Zondervan, 2015; Klöne and Zondervan, 2017).
*) The scores 'beautiful' for the different euro denominations are quite close to each other, except for the euro 5. When the interviewer is going through all denominations, several respondents answer that the euro 500, being the highest value, is to them the most beautiful euro banknote.

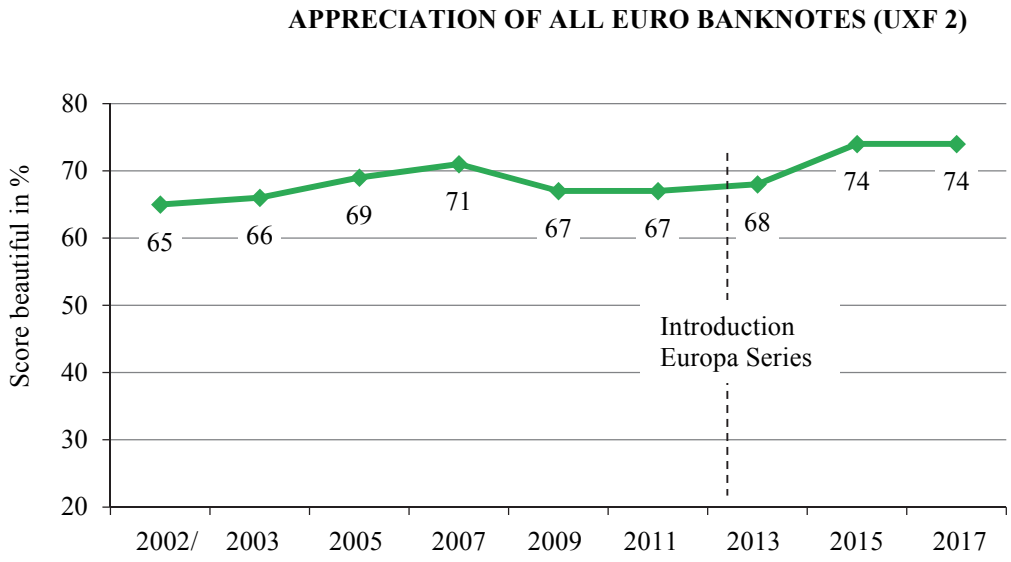


Figure 6.33
Appreciation of euro banknotes over the years 2002-2017.

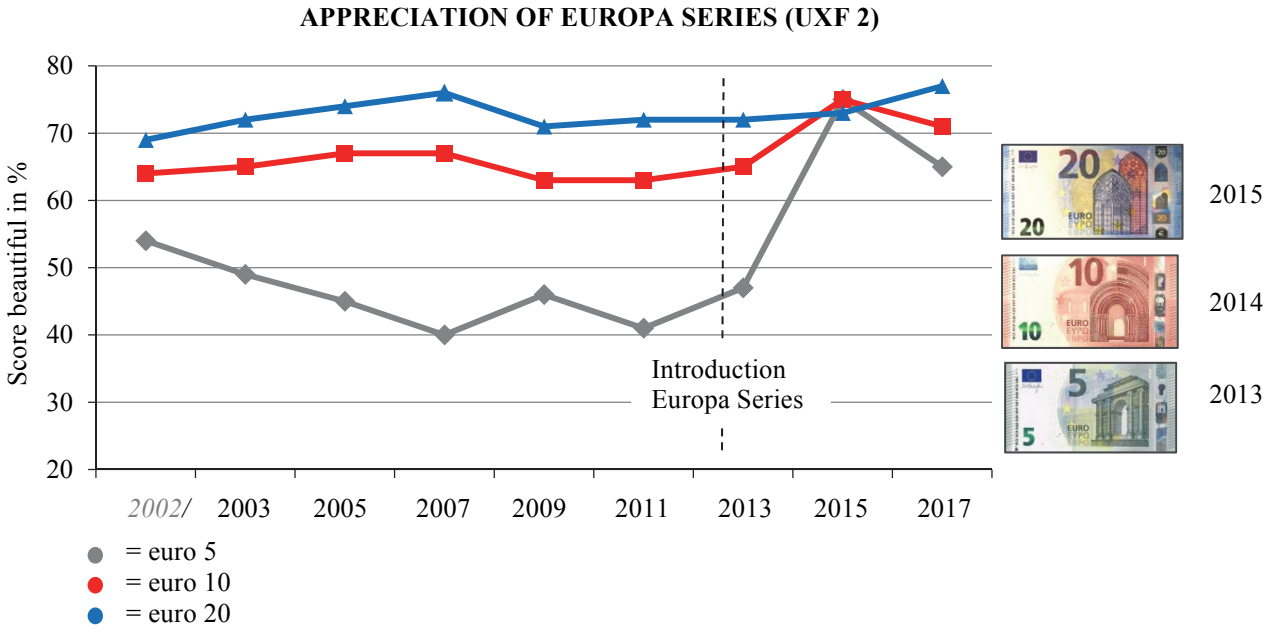


Figure 6.34
Appreciation of euro banknotes over the years 2002-2017. In 2013 the first model of the Europa Series was introduced (Klöne and Zondervan, 2017).

JUDGING AESTHETICS (UXF 2)			
			
Currency	**USD**	**CAD**	**EUR (NL)**
Denomination	20	10	50
Year	2003	2002	2003
Score	7.3	7.9	6.6

Figure 6.35
Three different banknote models compared for their score 'beautiful' (De Heij et al., 2003).
The score in '% beautiful' for the euro is converted into a report mark on a scale of 1 to 10 (66 % beautiful is a report mark of 6.6).

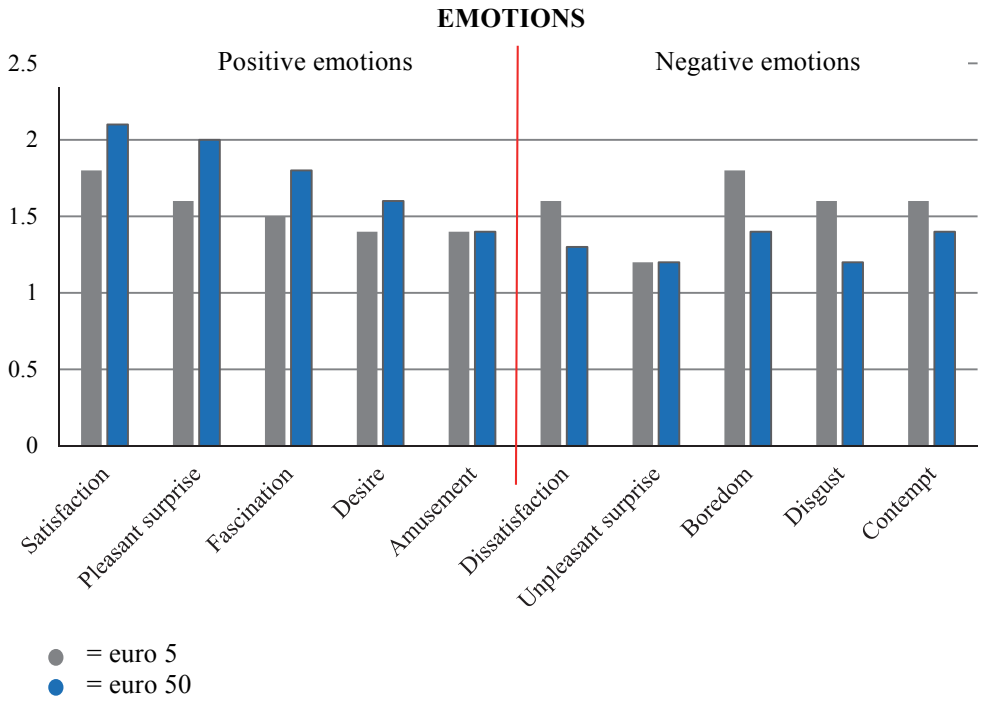


Figure 6.36
The euro 5 and euro 20 banknotes as compared on the PrEmo emotion scale from 1.0 - 3.0. On the left, the 5 positive emotions; on the right, the 5 negative emotions (De Heij, 2006a).

6.7.2 Emotions evoked by euro banknotes

Banknotes evoke emotions, as introduced in subsection 5.3.3. In 2005, a single measurement has been carried out to investigate the emotions of the euro 5 and 20 (De Heij, 2006a). To prevent a bias, these designs were offered without the large numerals and were made equal in size. In general, no strong emotions were registered, no positive and also no negative emotions (figure 6.36). The emotional satisfaction parameters for the euro 5 and 20 are respectively 1.8 and 2.1, on a scale from 1 to 3. These scores may be compared to the appreciation scores, which came out in 2005 on respectively 45 % (euro 5) and 74 % beautiful (euro 20). This suggests that the aesthetics influence the evoked emotions. These findings could have been used for future euro banknote designs, in case the Europa Series. High scoring negative emotions could have been reduced, i.e. boredom, and low scoring positive emotions could be increased, i.e. amusement.

6.8 Measurements of keeping confidence (UXF 3)

Confidence scores are reported by the Bank of Canada and by DNB. There are some differences between the two methods followed. Measurements by the Bank of Canada are done annually, while in the Netherlands the measurements have a biannual frequency. Furthermore, the measurement method is different. The Canadian confidence score is the aggregated result, presented as an index, of the responses to the following four attitudinal questions:
1) To what extent is counterfeiting a problem?
2) How likely are you to receive a counterfeit note within the next six months?
3) What is the likelihood that you will experience fraud or loss when using cash?
4) How confident are you in the systems currently in place to remove counterfeits?

The Dutch confidence score is a report mark, based on the question: “If you should give a report mark for your confidence in the authenticity of euro banknotes that you receive in your hands, what would be your score on a scale from 1 to 10?”.
At the peak in 2004, counterfeiting of the CAD 10 and CAD 20 notes reached 1,292 ppm and 601 ppm, respectively. Also in the Netherlands the number of counterfeits fluctuated, peaking at 109 ppm in 2009 and decreased in 2015 to about 100 ppm. The graph of figure 6.38 leads to the conclusion that up to a level of 500 ppm the level of mimicked banknotes does not seem to be of influence on people’s trust in banknotes.
Trust of the Dutch in their euro banknotes shows a slight upward trend (figure 6.37), which is mainly caused by the increase of respondents providing a score of 8 or higher (figure 6.39). This trust is justified, as elaborated on in the last part of subsection 3.4.3.

Several financial crises have been experienced since 2007 and the euro has been part of it. Up to date, this did not influence the confidence scores in the authenticity of banknotes (figure 6.37), a finding which raised the question of what is it exactly that people have trust in? Is it the banknote’s currency unit or is it the banknote as a payment instrument? Indeed, the Dutch do discriminate between these two economic functions (Visser and Dijkers, 2013). In 2013, the score for the euro as a currency was lower (6.7) than the score for the euro as a means of payment (7.1), both measured on a scale of 1 to 10. Future studies on this topic will have to show whether there is a trend for respectively the public perception of the euro as currency unit and for the euro as means of payment.

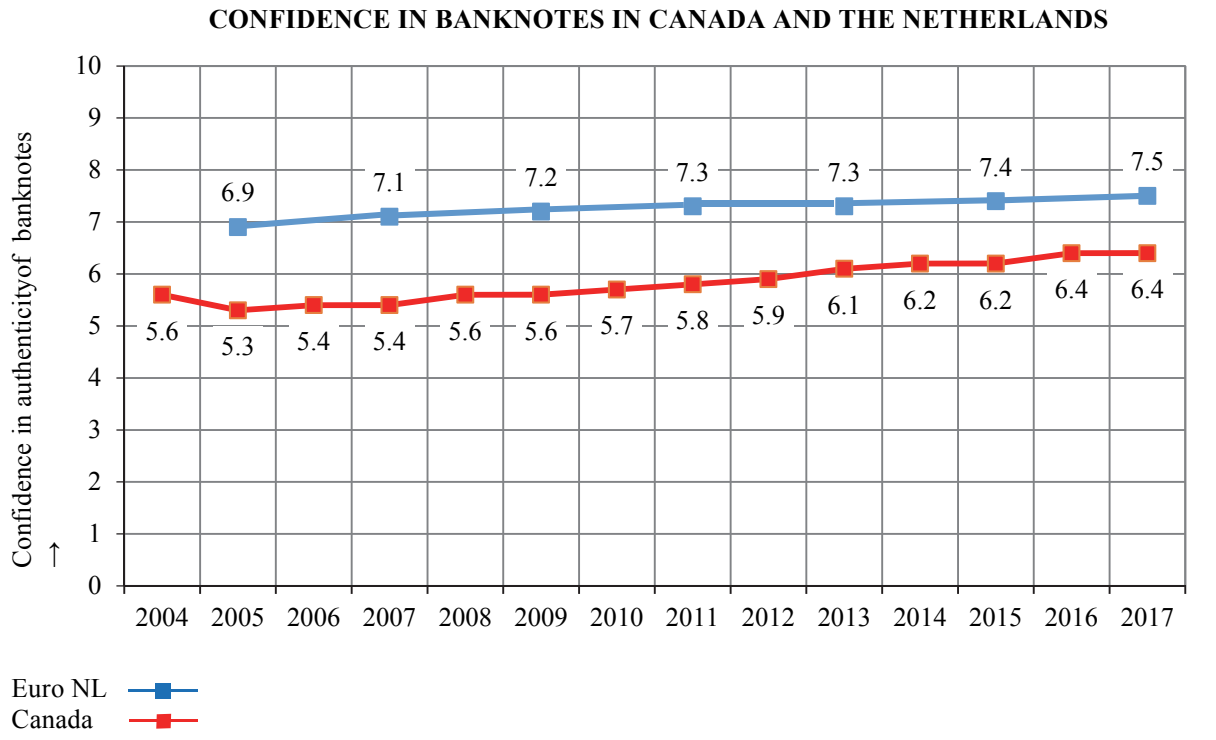


Figure 6.37
Confidence in the authenticity of Canadian banknotes, period 2004-2017 (Bank of Canada, 2009; 2017) and euro banknotes in the Netherlands, period 2005-2017 (De Heij, 2016d; Klöne and Zondervan, 2017).

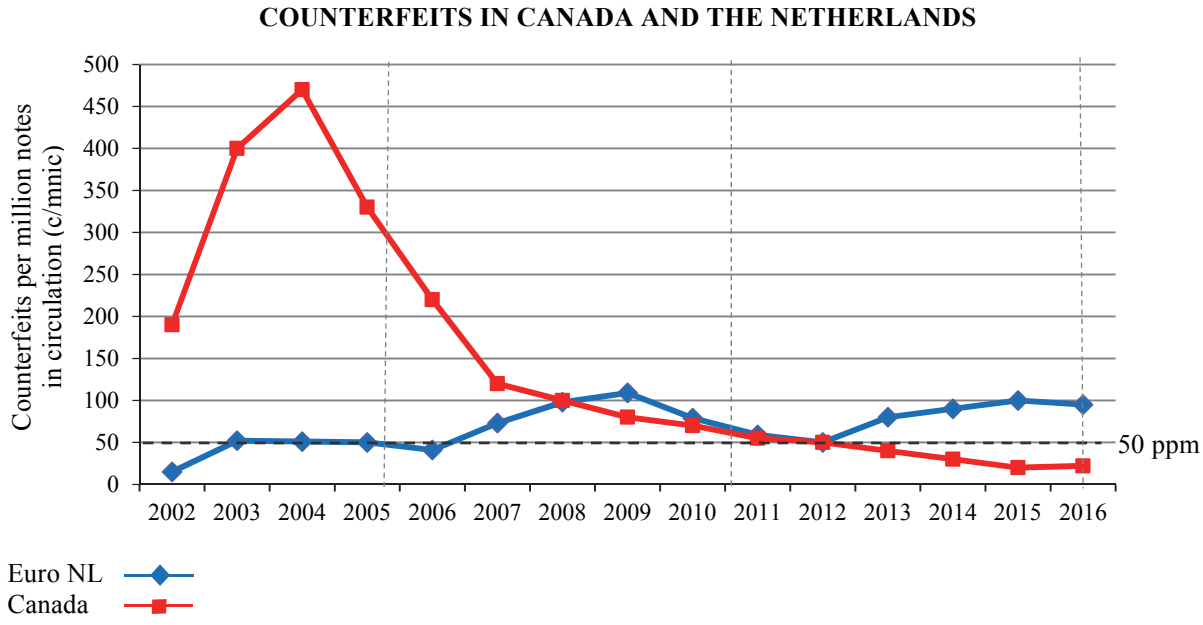


Figure 6.38
Development of the number of counterfeits (ppm) in Canada (Moxley, 2007) and the Netherlands over the period 2002-2016 (De Heij, 2016d).

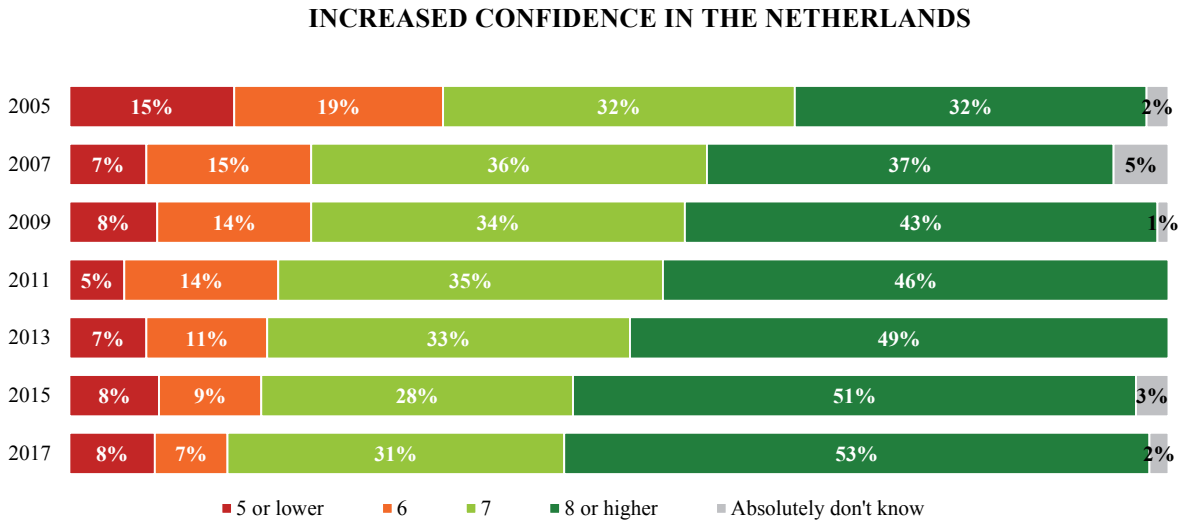


Figure 6.39
Increased confidence in the authenticity of euro banknotes in the Netherlands over the years 2005-2017 (Klöne and Zondervan, 2017).
The question asked is: "If you should give a report mark for your confidence in the authenticity of euro banknotes that you receive in your hands, what would be your score on a scale from 1 to 10?"

RECOGNITION OF MANIPULATED IMAGES		
Banknote	**Stimulus**	**Correct (%)**
Euro 5	Manipulated	16
	Real	85
Euro 10	Manipulated	28
	Real	79
Euro 20	Manipulated	44
	Real	77
Euro 50	Manipulated	42
	Real	53

Figure 6.40
Overview of the public recognition of switched main images on euro banknotes, including correct but for wrong reason (De Heij, 2009).

6.9 Measurements of reacting on the main image (UXF 4)

The main image is a dominant design element (subsection 5.4.4). Most likely, the main image will influence people's emotions (subsection 5.3.3). Two studies on an alternative main image reported in favour of a building (subsection 5.4.4).
This section continues with measurements on interference of memory paths of euro banknotes (subsection 6.9.1) and themes for euro banknotes as suggested by the Dutch (subsection 6.9.2).

6.9.1 Interference of memory paths

Switching main images on euro banknotes (figure 5.17) could be done without people noticing such major changes (De Heij, 2009; 2012). Replacing the arch on the 5 euro banknote by the window of the euro 50 was not noticed by 85 % of the respondents. Switching the gate of the euro 10 by the gate of the euro 100, was noticed by 28 % (including 13 % for the wrong reason, like a different ring of stars). The aggregated results are provided in figure 6.40.

6.9.2 Suggestions for banknote themes

The main theme of the euro banknotes is Ages and Styles of Europe, which is unknown to the Dutch (section 6.5). This finding triggered the question of what the Dutch would like to have displayed on the euro banknotes. The majority (52 %) finds it is difficult to imagine what should be depicted and those who came up with a recommendation provided a wide range of answers (De Heij, 2007). Pictures of well-known European buildings like the Eiffel tower, Acropolis and the tower of Pisa were prompted by 37 % of the respondents. This outcome suggests that the Dutch have no strong national feelings on a specific main image to be depicted on future euro banknote designs. In other words, the Dutch do not necessarily require euro notes with Dutch national symbols like clogs, tulips, windmills or Rembrandt. In order to achieve a better understanding of the European identity an additional single examination was carried out (De Heij, 2012). Respondents were asked: When you think about Europe, what would you consider to be typically European? Indeed, the euro was regarded, spontaneously, as the most typically European symbol (25 %), followed by the Eiffel tower (16 %), absence of borders (11 %) and Brussels (10 %). Youngsters mentioned the euro, Brussels and the European flag.

6.10 Measurements of requiring sustainability (UXF 5)

A measurement method aiming for the public's opinion on sustainable banknotes is not yet developed. A historical review of sustainable banknote topics is provided in section 4.6.
Measurements on neatness of banknotes have been reported as part of measurements of handling (subsection 6.3.2). Neatness of banknotes is also related to sustainability, as the replacement rate of banknotes will influence the environmental impact.
LCA-studies (subsection 4.6.2) delivered measurements for the environmental impact of cotton based banknotes versus polymer based banknotes. The outcome of these studies is that in general other variables, such as LED-screens of ATMs (Euro Aea) or transport costs (Canada), are found to be of more relevance than the banknote's substrate.
In 2015, the Dutch were for the first time interviewed for their opinion on the use of fair trade cotton in euro banknotes. The outcome was that a majority (77 %) accepts a slightly higher price for the cotton to meet sustainable criteria (Randsdorp and Zondervan, 2015).

6.11 Measurements of expecting a link with information technology

Studies reporting measurements on the public's reaction to a link between a banknote and information technology are unknown. When DNB's app "Genuine or counterfeit" was launced in 2015, over 80,000 downloads were registered in the first month. Other feedback is delivered by user reviews on the app. The app fulfils a modest role, so is the preliminary conclusion, which is explained by the stable situation concerning counterfeiting. In case of a significant increase of counterfeited euro banknotes, the Dutch may become more interested and my use the app more frequently.

6.12 Conclusions on measurements of the model's user functions

The main conclusion of this chapter is that the proposed Model for Use-centered Design of Payment Instruments is, in the case of banknotes, an appropriate framework to report measurements reflecting the users' perspective.
Measurements can be presented in longitudinal data and by single examinations. Time series and single examinations are available for UIFs and UXFs, except for UXF 6, the public's expectation for a link between a banknote and information technology. For the following user functions the measurement methods are immature: handling (UIF 2), receiving a communication message (UIF 4), experiencing identity (UXF 1) and requiring sustainability (UXF 5).

Measurements are available on value recognition of euro banknotes (UIF 1). Main images within a series of banknotes may be switched without being noticed as a result of interference of memory paths. When asked for a favourite main image, respondents in Canada, Germany and the Netherlands answer with buildings.

Handling banknotes (UIF 2), people take a banknote on the centre of the short edges. An optimal banknote size is the size of the euro 20: (length) x (height) = 133 mm x 72 mm. Respondents judged the euro banknotes as very clean; central banks may reduce the criteria for their fitness levels, especially when it comes to folded corners.

Several longitudinal measurements are available on an authenticity self-check (UIF 3). People recall two authenticity features, which seems to be a maximum. Even after a major event, like the introduction of the euro in 2002, the average did not exceed 2.3. Best recalled features in the Netherlands are a watermark and a foil with a hologram. However, people are not able to provide any further specifications of a watermark, like the image. A significant group is unable to tell any feature. Depending of the country, this group varies between 15 % and 50 %. The public prefers a foil stripe over colour changing features.
High ATM-notes tend to be the most counterfeited one, in the Netherlands the euro 50. In general, people withdraw this denomination from an ATM and do not receive them as change from a retailer. Retailers check this denomination by automatic devices. As a result, the attitude of the Dutch public towards an authenticity self-check is changing; the need for such a check has reduced.
People overestimate the amount of counterfeits far above the common threshold of 50 ppm. Counterfeiters mimicked about half of the public features, a figure which is stable over the years 2008-2015. This raises the question of whether a banknote should be replaced at this level of counterfeiting.
At the time of the Dutch gulden banknotes, relationships were investigated between people's knowledge of authenticity features (UIF 3) and the banknote's aesthetics (UXF 2). Most of the correlation tests suggested a relationship, but this relationship could not be confirmed for the euro banknotes.

Measurements on the reception of communication messages (UIF 4) suggest that messages incorporated in euro banknotes do not come across. The Dutch are unable to tell the theme and subthemes of the euro. In contrast, communication themes of Dutch gulden banknotes did come across, especially for the House-Tree-Animal Series.

The identity of the euro banknotes (UXF 1) is first of all expressed by the word 'euro' the map of Europe, the currency symbol and the flag of the European Union. The images of 'windows and gates' on the front and the bridges on the reverse hardly contribute to the experience of a European identity. Euro coins are experienced as being more European than the euro banknotes.

The dichotomous method proves to be efficient in bringing a score for the aesthetic quality (UXF 2), expressed in a 'score beautiful'. Over the years the appreciation of the aesthetics for a specific banknote model is constant, demonstrated by longitudinal data.
People are able to discriminate between the aesthetic qualities of different banknote models. Emotions evoked by banknote designs can be measured. Neither positive, nor negative emotions were measured in case of the euro banknotes.

Public's trust in banknotes (UXF 3) can be reported by longitudinal measurements as done in Canada and the Netherlands. Confidence scores turn out to be rather straight lines, independent from the number of counterfeits. Up to a level of 500 ppm confidence in banknotes is not influenced by the number of counterfeits.

Main images on euro banknotes (UXF 4) may be switched without being noticed.
Measurements are available which represents the users' interest in sustainable banknotes (UXF 5). First, Life Cycle Analysis will provide insights in the environmental aspects of banknotes. Second, the public's opinion on the use of fair trade cotton is measured. A significant part of (paper based) banknotes are yearly destroyed and a large part can be saved as people will accept folded corners and probably also less neat banknotes.

There are no measurements available on how well people judge banknotes to be linked to information technology (UXF 6).

The Upid-Model proved to be an appropriate framework to report on the banknotes' user functions seen from the users' perspective. When a *target* would be specified for each function, a new banknote design can be compared to the model it will replace. A banknote model can also be compared to any other banknote design or to a benchmark. In case of a benchmark, the score should, for example, be at least 7 on a scale from 1 to 10. Translated to the aesthetic qualities of a banknote, this implies that at least 70 % of the population should judge a banknote as beautiful.
An *Assessment Scheme for Banknote Design* is presented in figure 6.41.

ASSESSMENT SCHEME FOR BANKNOTE DESIGN					
Model for Use-centered Design of Payment Instruments (Upid-Model)			**Target**	**Realised (Euro 50, NL)**	
				Year	**Score**
UIF	1	Recognising value	> 98 %	2015	94 %*
	2	Handling	> 90 % clean	2015	89 %
	3	Checking authenticity	Av. knowledge of features > 3	2017	2.0
	4	Receiving com. message	(> 7)	-	-
	1 - 4	Usability score	> 7	2013	6.4
UXF	1	Experiencing identity	(> 7)	-	-
	2	Judging aesthetics	> 70 % beautiful	2017	74 %
	3	Keeping confidence	For complete series > 7	2017	7.5
	4	Reacting on main image	(> 7)	-	-
	5	Requiring sustainability	(> 7)	-	-
	6	Linking to IT	(> 7)	-	-
	1 - 6	Experience score	(> 7)	-	-

*) Combined score for recognising and handling euro banknotes (European Commission, 2015).

Figure 6.41
Assessment Scheme for Banknote Design, based on the Model for Use-centered Design of Payment Instruments. Targets are proposed by the author. The column on the right provides the values realised in the Netherlands for the euro 50 (Model 2002). For the targets set in parentheses, measurements are not available.

I begin with an idea and then it becomes something else.
Pablo Picasso (1881 - 1973)

CHAPTER 7
APPLICATION OF THE UPID-MODEL TO THE DESIGN OF BANKNOTES

7.1 Introduction

The question answered in this chapter is: Is the Model for Use-centered Design of Payment Instruments, the Upid-Model, an appropriate model to underpin the design of a new banknote? And if so, does it lead to another type of banknote designs?

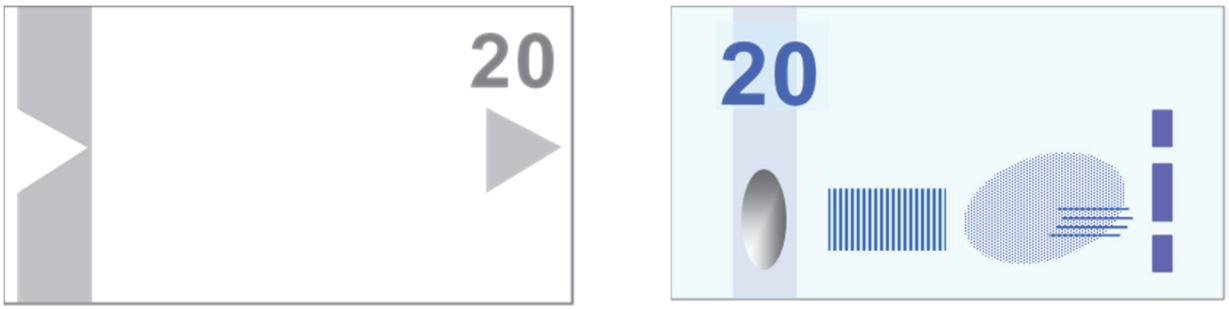
The conversion of banknote design requirements into a design is the job of the banknote designer (section 2.9). The designer can do this in several ways, like intuitive (subsection 1.1) or following a structured approach, like creating a *partial design concept* for each user function of the Upid-Model. An illustrative example is Monopoly Money (figure 3.4), as play money serves value recognition only (UIF 1). Several partial design concepts have been suggested by the author (De Heij 2007; 2009; 2010a; 2012; 2016b, like on handling or UIF 2 (figure 7.1a) and on checking authenticity or UIF 3 (figure 7.1b). Partial designs for other user functions have been introduced, like the conceptual design A-R-U-B-A (figure 3.33a) aiming for checking authenticity (UIF 3) and identity (UXF 1) and an anti-soil design (figure 4.18), serving sustainable banknotes (UXF 5).

A common stage within a banknote design process is the preparation of a *technical layout,* a drawing providing the optimal locations for machine readable features, a drawing following a concept as shown in figure 7.2a (De Heij, 2000; 2010a). This technical layout takes circulation effects into account such as folding lines, tears and folded corners. Figure 7.2b provides an illustrative example of a damaged banknote, demonstrating the benefits of a technical layout; machine readable features positioned in the quadrants will not be harmed by aging or other damages, or at least less. Banknote designers may also prepare a *functional layout*, a mixture of machine readable features and main design elements serving user functions, such as the main image and large numeral.
A further development of a technical and functional layout is the creation of a *usage layout,* to be prepared for each user function of the Upid-Model. A usage layout can be developed by the banknote designer or by a specialist. Subsequently, the different usage layouts are brought together into one design proposal, a *sketch design*. The Upid-Model will assist the designer further, because it provides a ranking of the user functions and the designer may super position the different usage layouts by following the ranking, like UIF 1 > UIF 2 > UIF 3 > UIF 4. Applying this method, the designer will arrive in several steps at a sketch design for a new banknote model (De Heij, 2016b).
A conceptual design is prepared for an imaginary currency unit MAX, Money of Area X.

This chapter reports on the creation of a use-centered design concept for a series of banknotes of an imaginary currency unit MAX (section 7.2). Subsequently, the conclusions are reported, providing an answer to the research question whether the Upid-Model is an appropriate model to underpin the design of a new banknote (section 7.3).

Partial design concepts for the public

Handling (UIF 2) Checking authenticity (UIF 3)

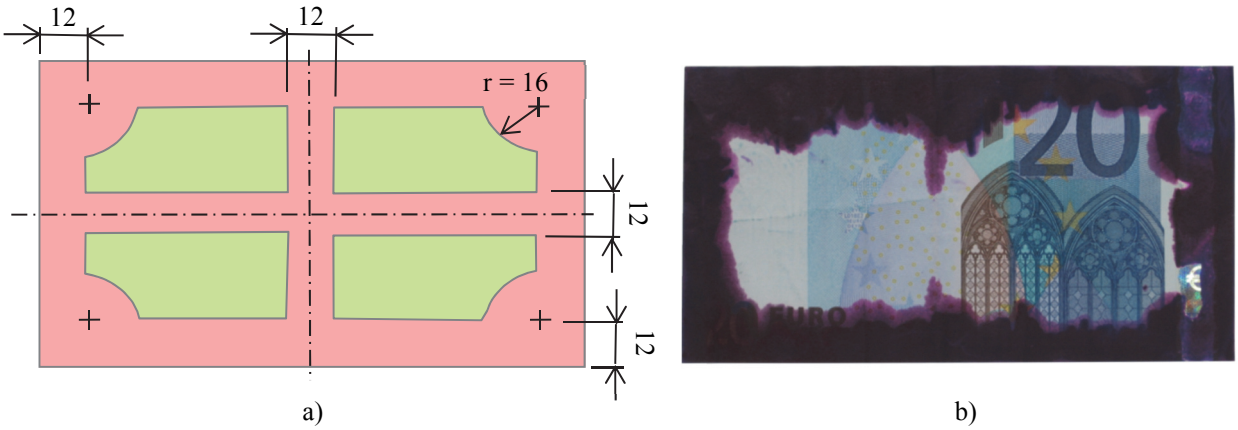


a) b)

Figure 7.1
Two examples of a partial design concept for public use (De Heij, 2007).
a) A design assisting the feeding of a banknote into a payment terminal for banknotes.
b) A design following the concept of "All features in a row". From left to right the public will find four features. This concept is further enhanced by colour, in case "Look for the blue", as all features are blue. The general motto is "Look for the colour", telling to look for the red features in a red banknote.

Partial design concept for machines

Areas for authenticity features Stained banknote



a) b)

Figure 7.2
Machine-readable features would need to be positioned in the quadrants of the banknote.
a) Technical layout of a banknote, showing in green the optimal areas in green for machine readable authenticity features (De Heij, 2000; 2009).
b) An example of a stained euro 20 banknote (2002) from a dye pack. Image: European Central Bank.

7.2 Use-centered banknote design

Ten user functions are identified by the Upid-Model and for each user function a usage layout can be prepared. Obviously, all ten user functions should be taken into account.
First, the orientation scheme must be established, as introduced in subsection 3.3.1. A horizontal front and a vertical back is the advised concept (figure 3.20, scheme C). People withdraw banknotes from an ATM in a horizontal position (figure 3.21a) and subsequently store them in a horizontal position in their wallet. The public uses the front of a banknote and only incidentally looks at the back (subsection 5.4.5), therefore the horizontal front will be the *public side*. Retailers store their banknotes in cash drawers in a vertical position and banknotes are also inserted vertically into the slot of a banknote acceptor (figure 3.21b), implying that the back will be the *retail side*, to be designed in a vertical orientation.
The proposed orientation scheme of a horizontal front and a vertical back is used before, like in Brazilian banknotes, shown in figure 7.3a and b. However, earlier concepts did not emphasise public or retail user functions.

7.2.1 Method for Creating a Usage Layout for Banknote Design

The application of a usage layout for each user function is a design method, and the name given to it is "Method for Creating a Usage Layout for Banknote Design". This Method can be applied, once the orientation of the front and the back are determined. The Method starts with the development of a usage layout for each of the user functions and ends with a sketch design. The preparation of a user layout is comparable to the preparation of a technical or functional layout. The focus in a usage layout is on the use of the banknote by the public, and second, on the use by the retailer.
For each user function a usage layout is prepared, schematically shown in figure 7.4a. These usage layouts are optimal design solutions for each user function. Once these partial designs are ready, the usage layouts are merged together, covering a usage layout for all user functions (figure 7.4b).
The Method as presented in figure 7.4 provides the generic principle, aiming for any user function. As user functions are divided in User Interface Functions and User Experience Functions, two optimal usage layouts can be developed respectively for all UIFs and all UXFs. How a banknote designer arrives at a usage layout is demonstrated and is a process of five steps:

1) Usage layout for each UIF,
2) Usage layout for all UIFs,
3) Usage layout for each UXF,
4) Usage layout for all UXFs,
5) Usage layout for UIFs + UXFs.

Subsequently, the Method continues with two more steps, respectively the stage from a usage layout to a blueprint (subsection 7.2.2) and from a blueprint to sketch designs (subsection 7.2.3).

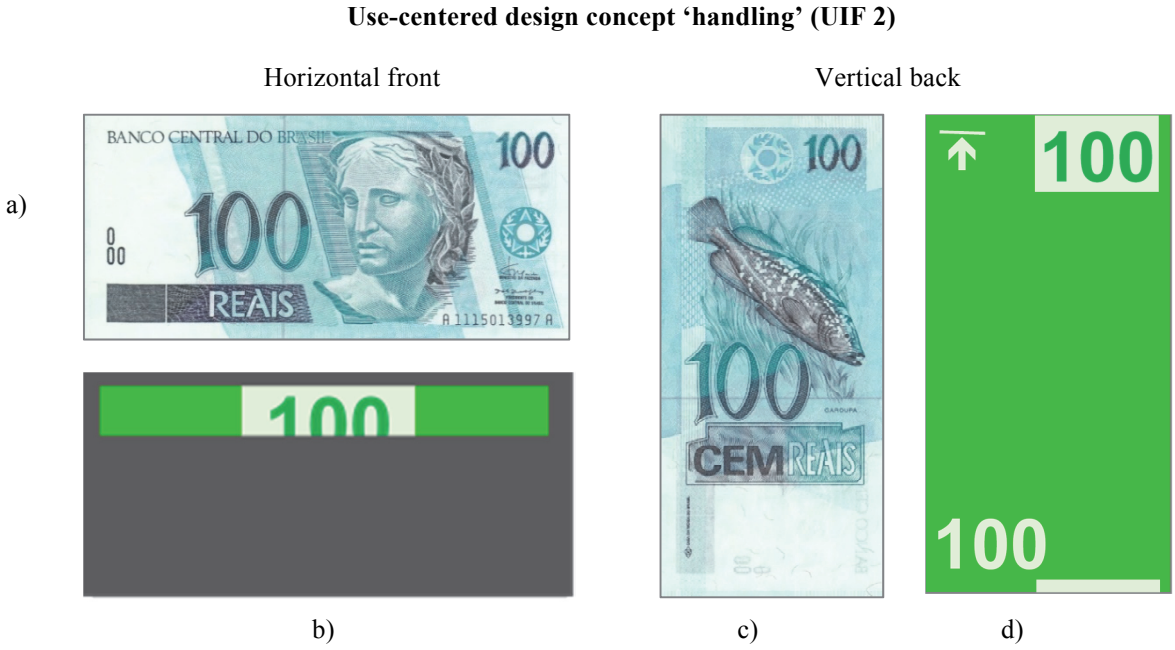


Figure 7.3
Banknote designs with a horizontal front and a vertical back (orientation scheme C in figure 3.20).
a) Horizontal front. Brazil, 100 reals, issued in 1994.
b) Horizontal front of a partial design concept for 'handling' (UIF 2). In a wallet, the colour and a large part of the numerals are visible.
c) Vertical back, Brazil banknote, 100 reals, issued in 1994.
d) Vertical back of a partial design concept for 'handling' (UIF 2). A banknote ready to be inserted in a banknote automate. Right handed people will hold the note on the bottom right.

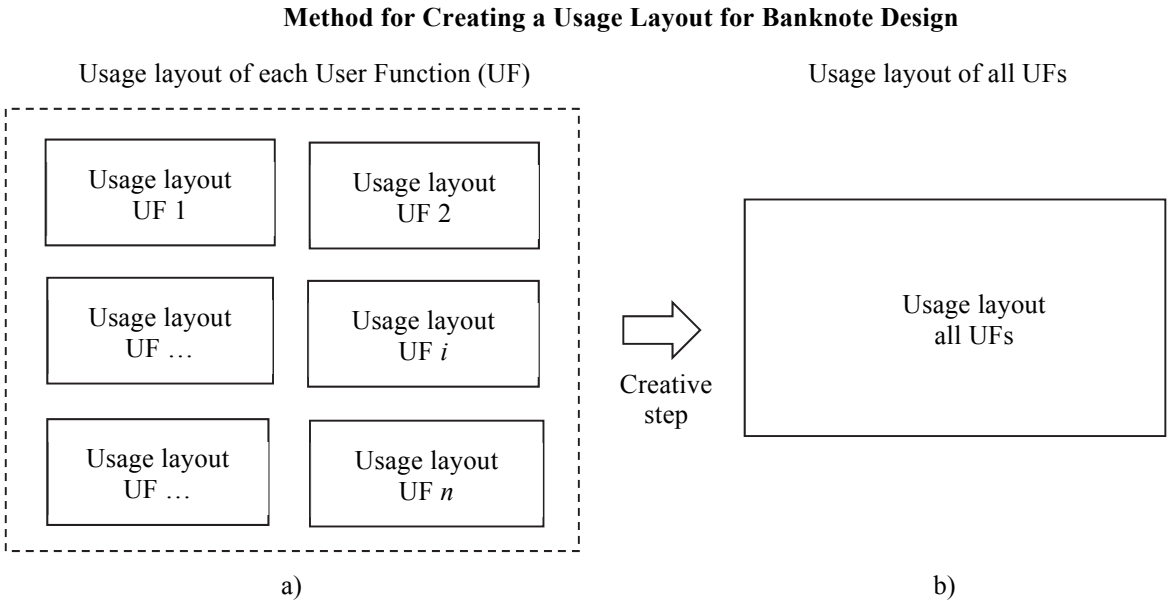


Figure 7.4
Schematic presentation of the Method for Creating a Usage Layout for Banknote Design for *n* User Functions (UFs).
a) A usage layout is created for each User Function (UF).
b) Usage layout for all UFs for the front of a use-centered banknote design.

Step 1 and 2: creating a usage layout for all UIFs
Chapter 3 on User Interface Functions provided insights into the user needs for each UIF, insights which can be applied to create an optimal usage layout for each UIF. The main area for value recognition (UIF 1) should be at the top of the banknote, so that this is readable when the banknote is in a wallet (figure 7.5a). Furthermore, the colours should run up to the edges. As a banknote may also be stored upside down, the numeral is also printed on the bottom.
People take banknotes (UIF 2) mainly at the short edges. Furthermore, the banknote's size should not be too small and should fit into a wallet (figure 7.5b).
Located in the quadrants, the public authenticity features (UIF 3) symbolise the guardian role of the banknote's value (figure 7.5c). More important is that these positions serve as signifiers (subsection 3.4.4) and will assist people to find the features. Furthermore, all authenticity features for public use are positioned on the front. Criticasters of such a concept may argue that counterfeiters may leave the back of the note empty. However, when retailers will verify the reverse, banknotes will be checked on both sides.
The design of a communication message (UIF 4) can be positioned at any place (figure 7.5d).
Finally, the individual usage layouts are grouped together in a *Usage layout for all UIFs* (figure 7.5e).

Step 3 and 4: creating a usage layout for all UXFs
Similar as the creation of a usage layout for all UIFs, a *Usage layout for all UXFs* is created. Chapter 4 provided insights on the user needs of these UXFs. As there are six User Experience Functions, six different usage layouts are prepared, illustrated by figure 7.6a-f, provided with a brief explanation.

Confidence features (subsection 4.4.4) can be organised within in a *confidence panel,* which integrates several confidence features (De Heij, 2011; 2012). A confidence panel follows a concept similar to a *language panel.* A language panel brings different languages together in one design element, like on Indian banknotes. A confidence panel will be associated with official papers, such as a notarial deed, the (red) ribbon of a diploma or the ribbons used in exclusive boxes of cigars or chocolates. The confidence panel in figure 7.6c is positioned near the short edge on the right, where most people will take the banknote, bringing users literally in touch with the confidence elements of a banknote (UXF 3).
Signing a letter or an email is done at the bottom, underlining the approval of the text above. Similarly, the signature on a banknote is positioned at the bottom right corner, underlining the approval of the complete design. Instead of the traditional signature, a small graphical element, similar to a photograph, communicates the guardian of the currency. In that case, people would recognise the person or wonder who it is. In the present time of image culture a more contemporary confidence feature than an illegible signature.
The date on the MAX-designs represents the date of issue or the approval date of the proof print (subsection 4.4.3).

In step 4 the individual usage layouts are grouped together in a usage layout UXFs (figure 7.6g).

Step 5: creating a usage layout for UIFs plus UXFs
The next step in the Method for Creating a Usage Layout for Banknote Design is to combine the usage layout of all UIFs with the usage layout of all UXFs to a usage layout for all UIFs + UXFs, as illustrated by figure 7.7.

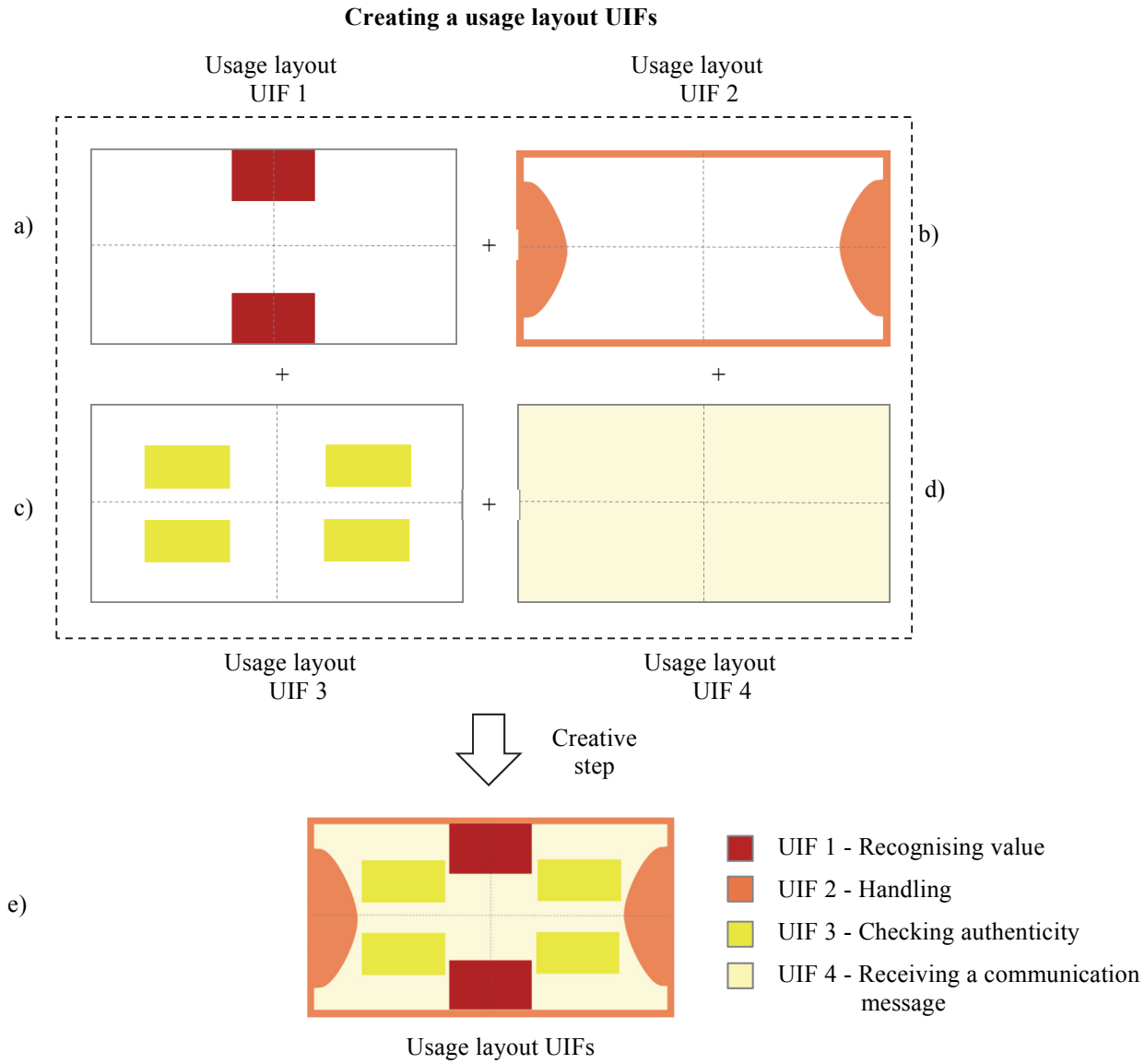


Figure 7.5
Schematic presentation of the creation of a usage layout for all UIFs.
a) Usage layout UIF 1, recognising value. People must recognise banknotes in their wallet. As banknotes may be upside-down, the value should be indicated at the top and at the bottom.
b) Usage layout UIF 2, handling. People take banknotes at the short edges. The size should not be too small and should fit into a wallet.
c) Usage layout UIF 3, checking authenticity. Public features only on the front. In each quadrant a feature, which makes them easy to find.
d) Usage layout UIF 4, receiving a communication message. A communication message can be anywhere on the banknote.
e) Usage layout UIFs. Different UIFs are well distributed over the surface.

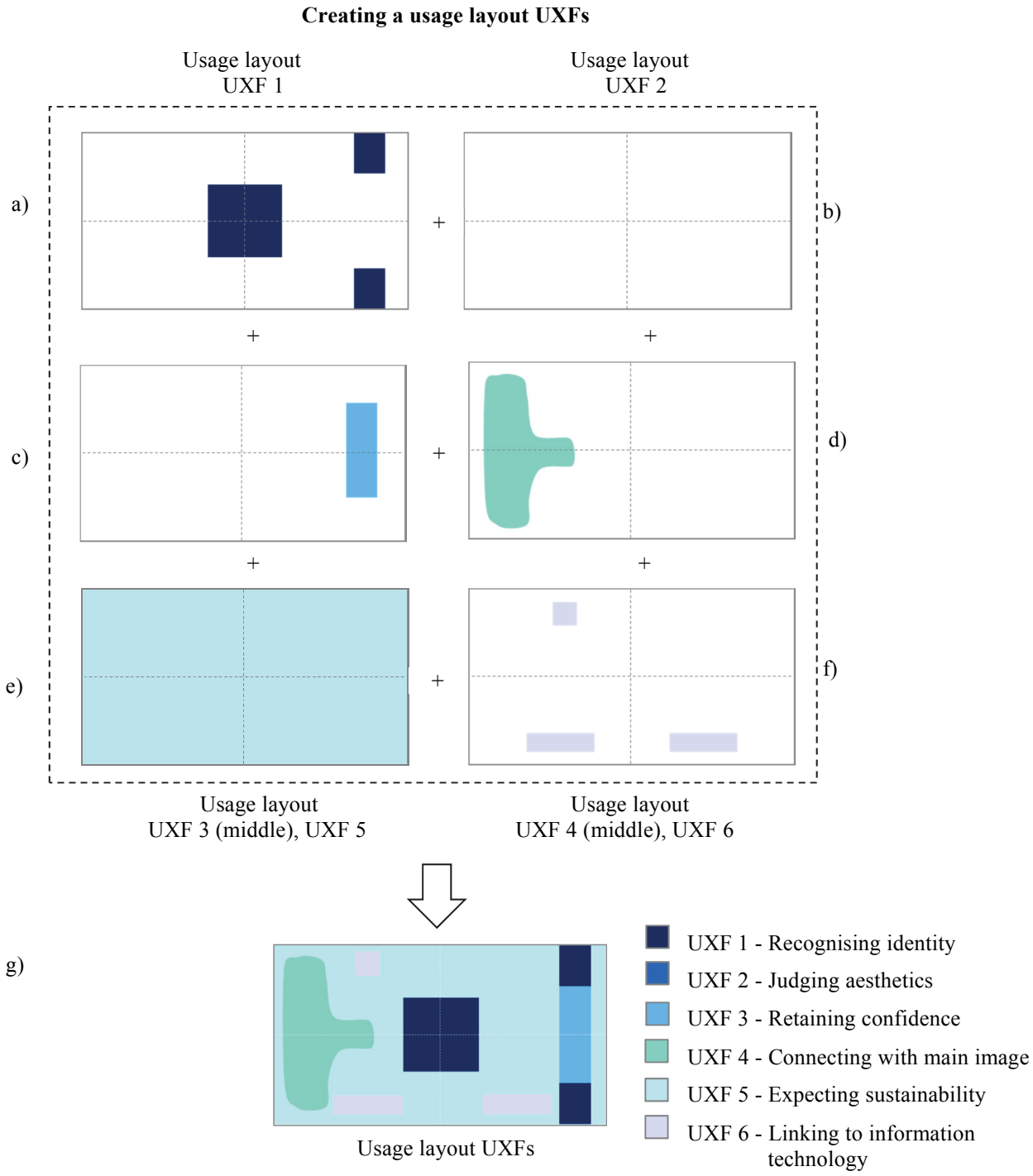


Figure 7.6
Schematic presentation of the creation of a usage layout for all UXFs.
a) Usage layout UXF 1, recognising identity. The currency unit is the core of the identity and the middle offers a good place. On the right side, there are two more areas reserved for identity design.
b) Usage layout UXF 2, judging aesthetics. Aesthetics cannot be marked. Concerns the complete front.
c) Usage layout UXF 3, retaining confidence. A confidence strip there were people touch the banknote.
d) Usage layout UXF 4, connecting with main image. Main image on the left, as most people are right handed.
e) Usage layout UXF 5, expecting sustainability. The complete banknote should be sustainable.
f) Usage layout UXF 6, linking to information technology. Banknote numbers are the link to IT and therefore on the front. Just like a QR-code.
g) Usage layout UXFs. Different UXFs are well distributed over the surface.

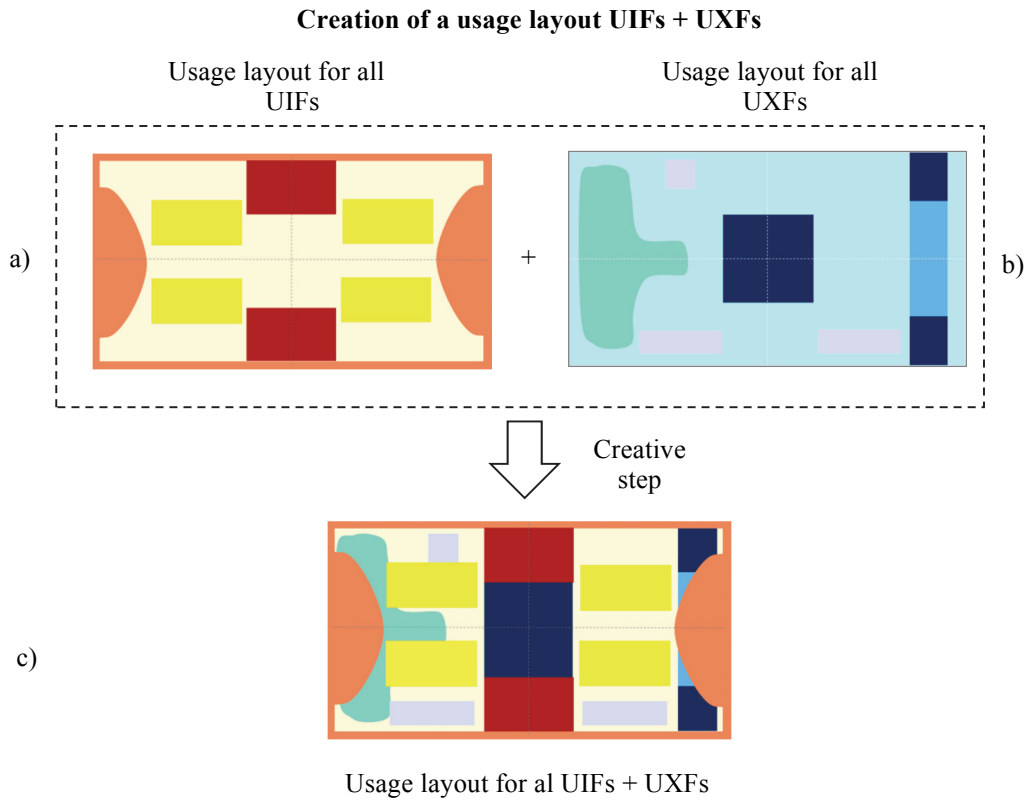


Figure 7.7
Creation of a usage layout for all UIFs + UXFs.
a) Usage layout for all UIFs.
b) Usage layout for all UXFs.
c) Usage layout for all UIFs + UXFs.

7.2.2 From usage layout to blueprint

The Method continues with the creation of a *blue print for the design of a new series of banknotes*. The combined usage layout for all UIFs + UXFs, the result of figure 7.7, is transformed to a blueprint as illustrated by figure 7.8. In this stage, the communication plan (subsection 3.5.1) should be ready. Furthermore, the design philosophy of the designer will be a personal guide to approach the design (section 2.1).

The imaginary currency 'Money of Area X', with the currency code MAX, will be the example for the preparation of a blueprint (De Heij, 2016b). The denominations and the colours have been proposed in figure 3.10.
First a *value panel* is developed, following a similar approach as the confidence panel. The value panel is prominently positioned in the centre. The *currency indication template* is at the heart of the value panel - and thus in the heart of banknote - and represents the full name of the currency and its proposed ISO-code MAX. After all, trust in banknotes is mainly trust in the currency. Furthermore, the value panel includes two large numerals in a vivid colour, one in positive and one in negative. The main image is positioned on the left, contributing further to the determination of the banknote's value. The design of the main image received a characteristic and recognisable outline, a 2D-image impression, rather than a 3D-type of pictures, supporting an optimal perception. Furthermore, these main images received an open structure, supporting UIF 3. Thick, maximum gravure lines are combined with the thinnest possible lines. As most people are right-handed, the main image is not covered in this position, when people take the note from their wallet.

The identity (UXF 1) of the MAX banknote series is based on an *identity description* (subsection 4.2.4) aiming for forward looking symbolism (subsection 4.2.2). The central value indication MAX will emphasise its identity.

Public authenticity features (UIF 3) are positioned on the front and are similar in size. Their design philosophy is based on the following thought. Individual citizens have their own *personal identity* and together they have a *group identity*. Therefore, one feature shows an 'individual variant' (figure 7.8b, feature 2) and one feature shows a 'collective variant' (figure 7.8b, feature 1). Their design is mainly figurative, as public features should be recognisable images with a name. These designs are also based on a 2D-image impression, like the main image. Usually, the most sensitive finger is on the reverse of the banknote and therefore the tactile areas are planned on the reverse.

Confidence in banknotes (UXF 3) starts with confidence in the currency. A confidence panel is proposed, introduced in topic 3, similar to the currency indication template. Banknote numbers contribute to confidence and therefore the banknote numbers are situated on the front.

A disputable user function is connecting with the main image (UXF 4). The function of a main image is mainly a contribution to instant value recognition (UIF 1). Still, the proposed images will invite people to bond with the design.

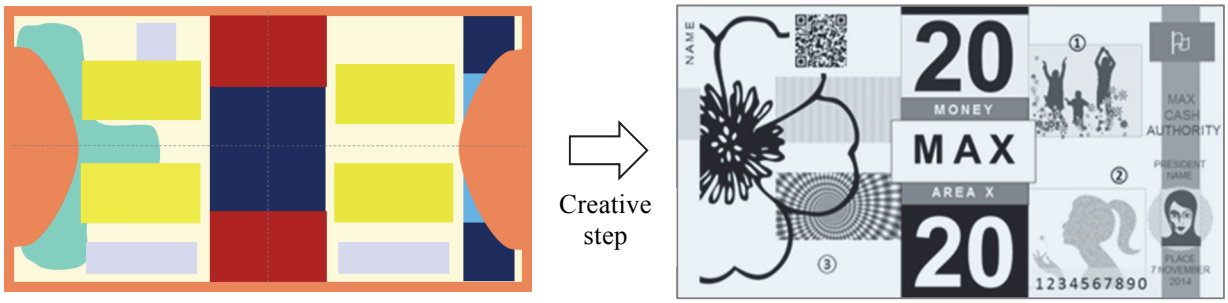
Banknotes are a utility product and modern citizens expect that their banknotes are sustainable, 'green' (UXF 5). The banknote designer has not many instruments to realise sustainable designs, because the sustainability of banknotes is mainly determined by its production. One of the design options is 'anti-soil design', by minimising the unprinted areas (figure 4.18).

A direct link between the banknote and information technology (UXF 6) is provided by a QR-code, a specific code for the denomination and the model. By scanning the QR-code with a smart phone, people may receive dedicated information of this banknote model, like information related to the public authenticity features. Furthermore, actual information may be provided on circulating counterfeits of this denomination, like the area where the counterfeiters are active. Information could also be provided on specific authenticity features, the ones that are the most helpful to assist the banknote user doing an authenticity self-check, discriminating between genuine and counterfeited pieces.

Form usage layout to a blueprint

Usage layout UIFs + UXFs

Blueprint series design



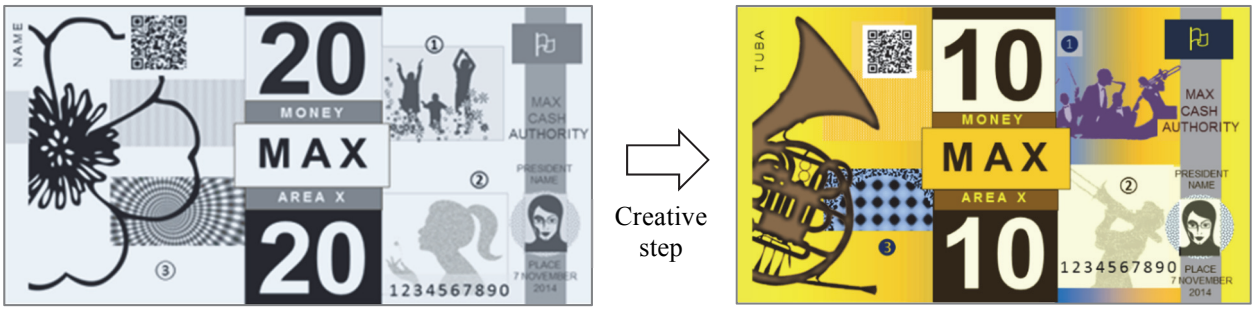
a) b)

Figure 7.8
From usage layout UIFs + UXFs to a blueprint for the design of a new series of banknotes.
a) Usage layout of the new banknote series (UIFs + UXFs).
b) Blue print for the design of a new series of banknotes.

From blueprint to sketch design

Blueprint series design

Sketch design of a denomination



a) b)

Figure 7.9
From blueprint for a series design to a sketch design for one of the denominations of a new series of banknotes.
a) Blue print for the design of a new series of banknotes.
b) Sketch design for one of the denominations of a new series of banknotes.

Use-centered banknote design - one denomination

Public side

Retail side

a) b)

Figure 7.10
An example of a complete banknote design concept, following a use-centered banknote design policy. The concept is made for the MAX 10/Horn. The music theme is displayed on both the front and the reverse. The names of the public features are respectively jazz, trumpet and blue. The features are signified by (1), (2) and (3), an example of search features (subsection 3.4.4).

7.2.3 From blueprint to sketch designs

The last step of the Method for Creating a Usage Layout for Banknote Design is visualised in figure 7.9, the step from a blueprint to a sketch design. The back of the MAX 10 is developed with a vertical orientation and follows the same stages as applied for the front. The result of this process, a blueprint for the reverse, is provided in figure 7.10b (De Heij, 2016b).
Like on the public side, the layout of the retail side is dominated by two large numerals (UIF 1). Facing the reverse in their wallet, people may read the smaller values on the long sides of the generic template (UIF 1). Handling of the retail side differs from handling the front (UIF 2) and the two large numerals received therefore a different position as on the front. One denomination numeral is positioned at the top, assisting people to insert a banknote into a machine, further supported by a *feeding arrow*. The other numeral is positioned at the bottom, on the left side, so that (right handed) people may verify which denomination they are feeding. People would most probably like to feed a banknote with one hand and therefore the banknote should not be limp. Increasing the stiffness of the banknotes is therefore one more option to be considered. Paper fibres could run parallel to the front's long edge, making banknotes bend less than in the case of short edge running fibres. Almost all banknotes carry a security thread in the paper and as a consequence paper fibres are short edge running in such notes.
Authenticity features for retailers are based on devices, which either need a human operation or are fully automatic devices, like a green or red signal indicating that a banknote is respectively genuine or a counterfeit. The design of the human operated features received a realistic design, matching with the theme of the banknote (UIF 4). The checkout scanners of the retailer may read a metameric code (figure 4.20). A barcode on the reverse delivers more reliable number reading as OCR-B numbering and represents the same banknote number as on the front.
When handling the retail side, shopkeepers and public will touch the currency indication, a link to experiencing confidence (UXF 3).

Figure 7.11 displays the front of all denominations of the MAX-series, a series designed to express the value of the different denominations (UIF 1). Banknotes are recognised by its colour and therefore the general colour perception should not be affected by a second or third colour. The main images are taken from different image categories, further improving value recognition (De Heij, 2009).
The MAX-series include a saving denomination, the MAX 1,000. The concept of this high value note is that it can only be received and exchanged at the counter of a bank, aiming for prevention of misuse of by criminals. Therefore, its design differs from the ATM-denominations (subsection 3.2.1). The MAX 1,000 received a larger height and length, making it impossible to insert this note into banknote machines like payment terminals or Cash Recycle Machines. Furthermore, this denomination received a horizontal back. To serve professional cash handlers, this high value denomination received additional authenticity features.

Use-centered banknote design - series impression

Name of the series is: Life”.

Horn

Flower

Bird

Man

Pisa

Figure 7.11
Conceptual proposal for a series of banknotes for the currency MAX.

7.3 Conclusions on applying the Upid-Model on banknote design

The Upid-Model is explored in its role of providing a foundation of new banknote design. A design exercise is presented for an imaginary currency MAX, Money of Area X. The MAX-design is founded on user preferences. Consequently, the design is user-friendly, at least in theory. The next step in a use-centered design approach would be to test the prepared designs with future users. However, this exercise has not been part of this thesis.
First, the orientation of the front and the back is determined. Based on a use-centered approach the front received a horizontal format and the back a vertical one, respectively referred to as a public side and a retail side. The public uses the vertical side when they insert a banknote into payment terminal.
A novel method has been developed to transfer design requirements into a usage layout, the Method for Creating a Usage Layout for Banknote Design. The Method aims for separate, optimal designs, called usage layouts, for each of the User Interface Functions and User Experience Functions. Dedicated specialists may be consulted to develop an optimal usage layout for each user function, like user researchers.
Subsequently, the banknote designer superpositions the developed usage layouts on top of each other, arriving at a usage layout for respectively all UIFs and all UXFs. From there, a blue print is created which is the basis for sketch designs of each denomination.
The Upid-Model has the potential to deliver use-centered banknote designs, designs based on user requirements. This novel approach provides an advanced look to the banknotes designed (figure 5.24).

Don't throw away your old shoes
until you have got new ones.
Dutch proverb

CHAPTER 8
APPLICATION OF THE UPID-MODEL TO THE DESIGN OF DIGITAL PAYMENT INSTRUMENTS

8.1 Introduction

Banknotes are losing market share to other means of payments. As the user of a payment instrument can be seen as a constant - the user of a banknote is considered to be the same person as the user of a debit card - the question arises whether the Model for Use-centered Design of Payment Instruments, the Upid-Model, is also applicable to other payment instruments, especially digital means of payment.

The introduction of digital payment systems led to the suggestion that societies will become cashless (e.g.Wolman, 2012). Indeed, digitisation of payment techniques reduced the use of banknotes, a development, which started with the arrival of main frame computers in the 1960s. Up to then people lived in *cash societies*; payments, including salaries, were settled in coins and banknotes. In these times, central banks indicated the proportion of cash money by the *cash currency ratio.* This ratio is defined by the proportion of cash currency, as part of all money deposited at the commercial banks. How coins and banknotes circulate in the society is known as the *cash cycle*. There are many descriptions made, for example by Van den Kommer and De Heij (2008) and recently by the European Central Bank (2017a).

Modern societies have evolved from a *cash society* to a *multi-payment instruments society* (Kosse, 2014). The current *payments landscape* is changing (Leibbrant, 2016).
A comprehensive historic overview of the development of payment instruments is not available. Overviews are often presented as an *infographic* (Infograhics Zone, 2016). Milestone overviews are provided by Mooij and Dongelmans (2004) and De Heij (2012; 2016a). These overviews are not consistent and are in need of a comprehensive study. However, all overviews include the transition of tangible money to electronic means of payments, often marked by the year 1871, when Western Union offered money transfer services by telegraph. Another milestone is the introduction of the first bankcard for consumers in 1950 by Diners Club International. Bankcards gave a boost to the transition of cash to electronic payments. Since the 1980s, *electronic payments* evolved to *digital payments*.

From the first coins around 700 BC, new forms of payment have been introduced, schematically presented in figure 8.1, illustrating that existing payment instruments do not completely disappear. After coins, banknotes appeared in 1661. *Incremental innovations* have improved the coins and banknotes, but cannot be compared to several *disruptive innovations* that followed within the payments landscape. The last decade, *fintech companies* (figure 2.10b) delivered several disruptive innovations. Payments by smartphones, the first in 2010, may (partly) substitute payments done with bankcards and cash. A next payment channel could be based on block-chain technology, as first applied in the Bitcoin (2007), but will probably not fade out previous payment channels. New disruptive innovations will follow-up on block-chain technologies. Central banks face new challenges. Payment systems are not only depending on technical innovations, they are also depending on social factors. Kenya moved in 2007 directly from cash to mobile payments, called "M-Pesa", skipping the phase of payment cards.

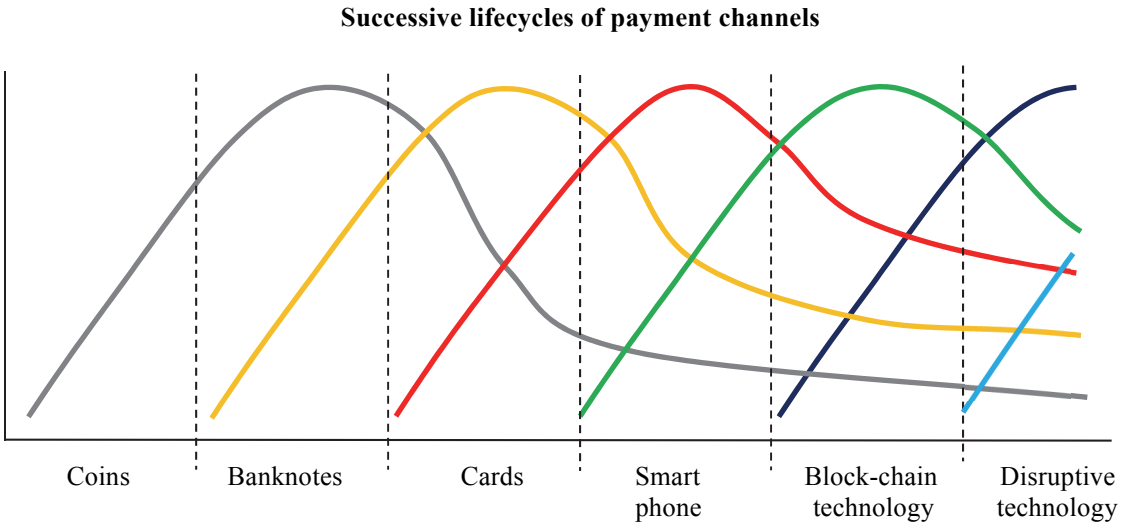


Figure 8.1
Principle of successive product lifecycles of payment channels. New payment channels may appear, but existing ones do not seem to fade out.

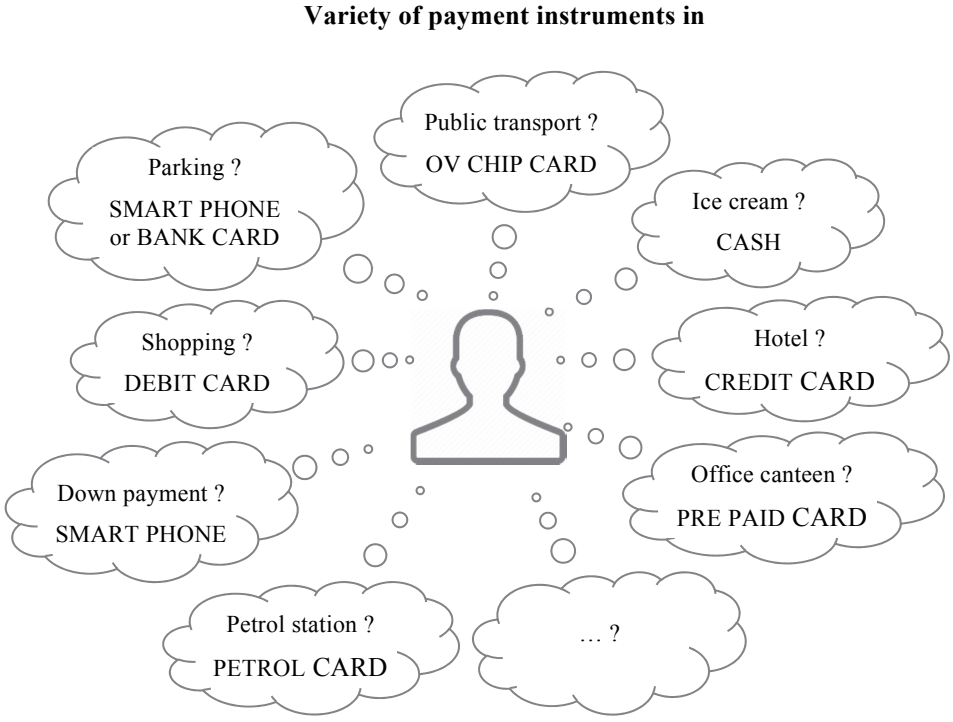


Figure 8.2
People have to think about the payment instruments that they may want to use.

People opt for a payment channel, and the accompanying payment instrument, which matches best to their user criteria. With so many different payment channels, people can - and often are forced - to make a choice. Consumers' payment behaviour is strongly driven by socio-psychological factors (Van der Cruijsen and Van der Horst, 2016). This study reports that emotions and attitudes determine how a person will make a payment. Habits also play a significant role in the way consumers actually pay at the till. The study further reports that users associate digital payments with ease of use, quickness and security. All means of payment must be secure and widely accepted, but privacy is more closely associated with cash payments. However, it is not yet clear which digital payment channel, including its instruments, will become the public's favoured one. As there are several different payment situations, a person must consider what type of payments might be encountered upon, illustrated by figure 8.2 (De Heij, 2012). Preparing themselves, people may nostalgically think back to the days when cash was king and was accepted everywhere, like when paying for parking their car. Nowadays car parking requires either a parking app on a smart phone, a credit card for easy access to a parking building, or a debit card when paying at a terminal. Occasionally, people may still pay for parking by cash.

The first publications on user criteria for payment instruments appeared around the year 2000. Van Loo et al. (2001) reported five criteria, which will be discussed in subsection 8.2. User criteria for banknotes are reported by the National Research Council (2007). A Danish publication (Jacobsen et al., 2011) reported in more detail on user criteria, followed by a similar study by the Bank of Canada (Arango et al., 2012). A study on payment behaviour in the Netherlands discriminates seven user criteria (Van der Cruijsen and Van der Horst, 2016). In 2014, a Dutch study elaborated on a single user criteria, budget control (Hernandez et al., 2014).

This chapter reports first on the banknotes in a changing world of payment systems (section 8.2). Subsequently the Model for Use-centered Design of Payment Instruments is applied to digital payment instruments (section 8.3). In a separate section the lessons learned from use-centered design of banknotes are reported, relevant for the design of use-centered design of digital payment instruments (section 8.4). This chapter ends with conclusions (section 8.5).

8.2 Banknotes in a changing world of payment channels

The analyses of banknotes in a changing world of payment channels starts with the transition of cash to digital payments (subsection 8.2.1). Subsequently, the instabilities in the cash cycle are discussed (subsection 8.2.2), followed by the user criteria for any payment channel (subsection 8.2.3).

8.2.1 Transition from cash to digital payments

In 1900, the cash currency ratio in the Netherlands was around 85 % (Mooij and Dongelmans, 2004). This ratio dropped in the 1960s to about 50 % because of the introduction of automatic salary payments and direct debiting of periodic payments, like mortgage and energy. Thereafter, the decline of cash accelerated because of the technological developments of payment systems, especially of bankcards. The banks deployed an ATM-network aiming for a reduction of the cash issuance at the counters of their branches, using the adaptation of bankcards by the public. The first ATM in the Netherlands appeared in 1976, operated by the Gemeente Giro in Amsterdam, while worldwide the first ATM was operated by Barclays in London in 1967. With 24/7 access to banknotes people no longer had to queue up on Friday afternoon to collect their banknotes for the weekend. Because of their unlimited access, ATMs are also known as *convenience ATMs*. Indeed, people appreciated ATMs and their breakthrough, also in the Netherlands in the early 1990s (Schaap and Van Vliet, 1991). The Dutch opted for the debit card and the first payment with this type of card was made in 1988 at a super market checkout of Albert Heijn.

Although the introduction of the ATM encouraged the use of cash, it was not enough to change the trend of a declining cash currency ratio, which dropped further to about 25 % in the last decade of the Millennium. At the time of the introduction of the euro coins and banknotes in 2002, the gulden era ended with a cash currency ratio of just 15 %. By the year 2007, the cash currency ratio was about 5 %. Nowadays, this figure is no longer reported by DNB.

As electronic money substituted cash money, cash payments remained either a transaction at a Point of Sale or a transaction from *Person to Person* (P2P). In 2015, the number of cash transactions in the Netherlands dropped for the first time below 50 %, while the number of debit card transactions increased. An overview of all payment transactions in the Netherlands in 2015 is provided in figure 8.3, based on data and estimations in the literature (Jonker et al., 2012; Van der Cruijsen et al., 2015; De Nederlandsche Bank, 2016). By 2019, it is expected that POS-transactions in cash will about 40 % of all POS-transactions (Snoei et al., 2015). This may drop further to around 15 %, as is already the case in Norway and Sweden (De Nederlandsche Bank, 2017).
The number of cash transactions as part of POS-transactions is falling, not only in Norway, Sweden and the Netherlands, but also in Australia, Austria, Finland, and the United Kingdom (Bagnall et al., 2014; Scholten, 2017). The Bank of England thinks that "Cash is not likely to die out any time soon." (Fish and Whymark, 2015). The Swiss National Bank (2016b) reported that "cash is still frequently used as a method of payment", a statement made in on the occasion of the issuance of a new Swiss banknote. Obviously, the transition of cash to digital payments has different speeds. There are some signals that South Korea may start with the abolishment of the coins, as a stepping stone to abolish cash in 2020 (Yang, 2016). However, cash is still a major payment system in many economies, such as Brazil, China and Russia, where over 85 % of the payments are settled in cash. In India, cash payments still account for 99 % of all POS-payments. A recent study on cash usage in the Euro Area reports that 80 % of the transactions at a POS are in cash (European Central Bank, 2017b).

The introduction of contactless payments will provide debit card payments a boost. However, the acceptance of disruptive payment innovations tends to be slow. Only a few early adopters use new payment instruments, like their smartphone, ending up in figure 8.3 with a negligible share of less than 0.5 % in 2015. Studies demonstrate that people tend to be conservative towards changes within payment systems (Contini et al., 2011). In the case of cash, people seem to have *ingrained habits* (Krüger and Seitz, 2014). Another study showed that, in parting with their money, people experience different emotions, coined as the "pain of paying" (Zellermayer, 1996). Non-cash payments are experienced as being less painful than paying cash (Van der Horst and Matthijsen, 2013).

8.2.2 Instability in the banknote's cash cycle

There are three main players within the cash cycle, public (1), retailers (2) and commercial banks (3) and their relationship is displayed in figure 8.4 (De Heij, 2012). Three different symbols indicate their attitude: positive (+), neutral (o) and negative (-). The attitude of the different parties towards cash are dissonant, creating instability within the diagram, an indicator of future changes.
The public initiates the banknote flow by withdrawing banknotes from an ATM and bringing these notes to the shops (+). Although retailers in the Netherlands accept cash, they prefer to receive debit card payment for safety reasons (De Nederlandsche Bank, 2015a). However, a clear majority of retailers (81 %) does not actively discourage their customers from making cash payments, as they believe their customers' preferences should always be accommodated (o). Debit cards may be safer, but retailers see cash as an alternative means of payment, providing business continuity, as most the Dutch retailers (59 %) say that they experienced malfunctions with one or more of their payment terminals during the previous six months.

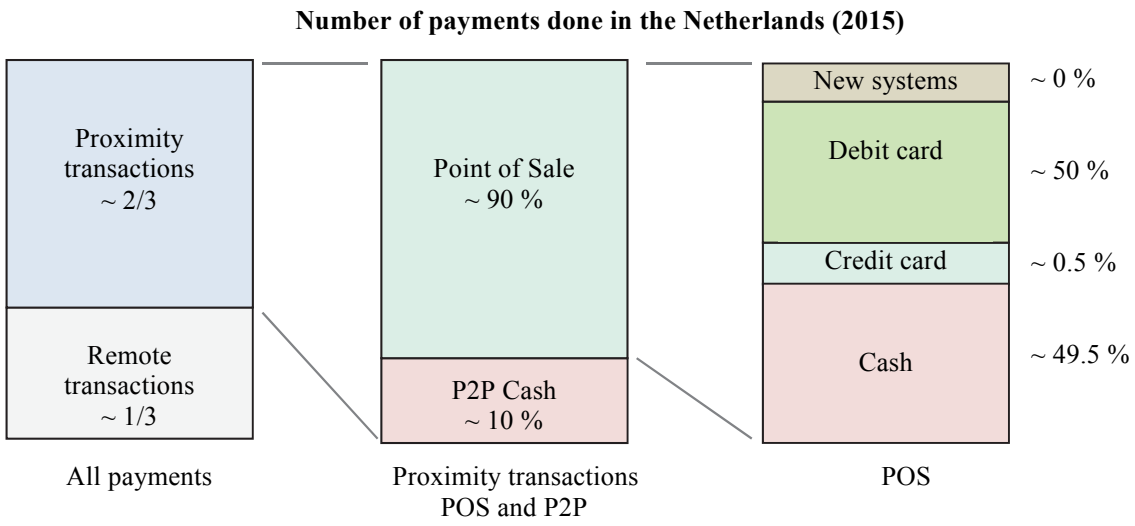


Figure 8.3
Breakdown of the *number* of payments done in the Netherlands in 2015. The columns "All payments" and "Proximity transactions by POS and P2P" are based on estimations.

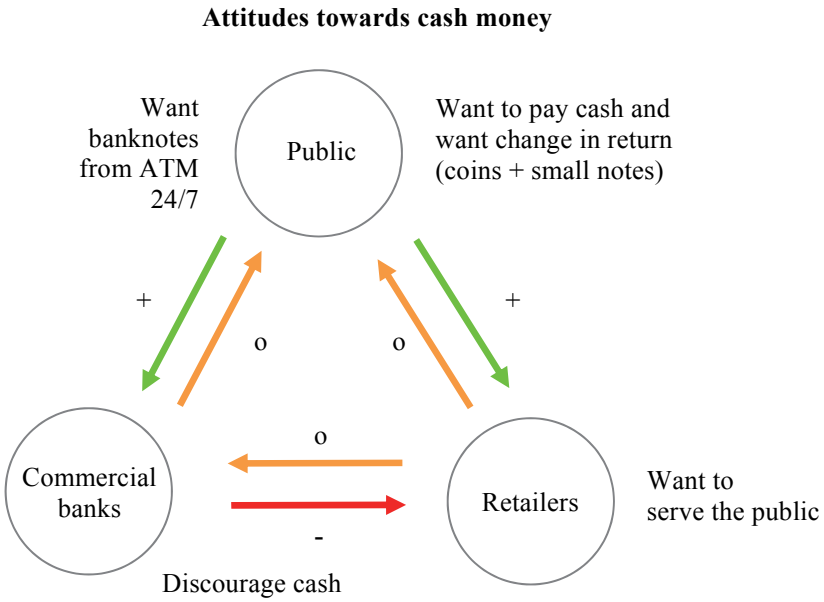


Figure 8.4
The attitudes of three different parties towards cash money. The public has a positive attitude towards cash (green, +). They want banknotes from their commercial banks and they want change from the retailer (banknotes and coins). Commercial banks and retailers fulfil this public need indifferently (orange, o). Retailers are also clients of the commercial banks and require deposits and withdrawals, especially coin availability to provide change to the public. The attitude of the commercial banks to cash money is rather negative, because of the handling costs, security risks and lack of income on cash holdings.

With the public bringing in cash, retailers experience two problems. The public brings in low coins and high denominations. Second, retailers have a systematic shortage of change, because of the high ATM-notes brought in by the public. The banks discourage coin and banknote orders by charging relatively high fees for these services (-). To avoid these tariffs, surpluses and shortages in change are partly exchanged between different retail branches. A fast food cafeteria with a surplus of coins may swap coins with a shop owner with a surplus of banknotes (Mathijsen and Scholten, 2012). Any remaining shortages of coins and low banknote denominations are pragmatically ordered by retailers at their banks (o).

Commercial banks acting in the cash cycle experience several disadvantages. One of their primary concerns is the physical involvement in the supply chain. They are confronted with ram raids of their ATMs and attacks on their armoured carrier companies. Usually banks outsource this type of activities to cash processing companies, servicing the recirculation of coins and banknotes.
On the income side, commercial banks receive no interest fee on their cash stock, while non-cash payments may bring them some profit on their bank account. Furthermore, commercial banks are often shareholder of debit and credit card organisations. Finally, bankcards display the name and logo of the bank.
As a result, the attitude of commercial banks towards cash is to eliminate cash payments and promote digital means of payment. However, public and retailers are both clients of commercial banks. Their attitude towards these two clients asking for cash is different, indifferent to the public (o) and discouraging towards retailers (-).
A criterion for access to banknotes is the number of ATMs per 1,000 inhabitants, which is in the Netherlands 0.5 ATMs per 1,000 inhabitants. Another relevant user requirement is the distance to an ATM, aiming for an ATM for every citizen within a radius of 5 km (Nederlandse Vereniging van Banken, 2004). Furthermore, ATMs should also be accessible from a wheel chair and for visually impaired.
The accessibility of the Dutch payment systems is monitored by the independent National Forum on the Payment System reporting every three years (Maatschappelijk Overleg Betalingsverkeer, 2016). The number of ATMs is declining, although in 2016 still 98 % of the Dutch found in 2016 an ATM within a 5-km radius (99.7 % in 2014). In 2014, it was a novelty in the Netherlands when a small Dutch village, the municipality of Ubbergen, contributed euro 10,000 to the placement of an ATM, to support access for their citizens (Havermans, 2014).

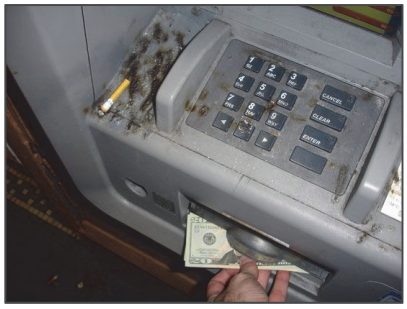
Cash users may face several disappointments, like a banknote being dirty, damaged or showing missing pieces (figure 8.5a). The *user environment* of banknotes may push potential banknote users away, for example when an ATM is out of order or dirty (figure 8.5b). Another disappointment is a banknote acceptor, which is not ready for a new banknote (figure 8.5c). Finally, the amount of change received in coins can be considerable and is another example of an unpleasant surprise (figure 8.5d). Other developments also influence reduced cash usage, like modern wallet use (subsection 3.3.2). As people tend to replace their banknote wallets by cases for cards or smartphones, people may store a banknote, but not coins.

Central banks may worry about the developments of cash, like losing market share and unpleasant surprises for cash users, but these should not be their only worries. A topic which receives not much attention yet, is the *image* of cash, which develops itself in an unwanted direction, illustrated by figure 8.6. Crimes associated with high denominations have been introduced (subsection 2.4.3), such as tax evasion (figure 8.6a), ransom money (figure 8.6b) and financing terrorism. Banknotes are also stolen, like in case of hold ups (figure 8.6c), ram raids of ATMs (figure 8.6d) or attacks on CiT-companies. Several central banks discontinue banknote denominations on a short notice (subsection 4.4.1), which brings mistrust and contributes to a poor image.

Unpleasant surprises with cash

a)

b)



c)

d)

Figure 8.5
Impression of unpleasant cash surprises. Images 8.5 a, b and c: public domain.
a) Damaged banknote.
b) Dirty ATM.
c) Acceptor does not take new banknote. Colmar, France 2013 (photo: Marcel van der Woude).
d) Many coins as payback.

Unlawful activities with banknotes

a)

b)

c)

d)

Figure 8.6
Impression of unlawful activities with banknotes. All images: public domain.
a) Tax evasion and money laundering.
b) Ransom money.
c) Robbery, hold ups.
d) Ram raids of ATMs.

8.2.3 User criteria to any payment channel

The previous reported on the changing world of paying with banknotes (subsection 8.2.1) and the instabilities in the cash cycle (subsection 8.2.2). These developments raise the question about the user criteria for any payment channel, what are they? Knowing these user criteria are relevant for future developments. Such an exercise may also unveil the differences between the user criteria for cash and the user criteria for digital means of payments.

The overarching criteria for any payment channel is *access* (Kosse and Jansen, 2013). With a bank account people will not only have access to ATMs, but also to other financial services, known as *financial inclusion*. There are several types of bank accounts, such as *checking accounts*, *saving accounts*, *line of credit accounts* and *mortgage accounts*. In the Netherlands, daily payments by a debit card are typically done by a card linked to a checking account.
One of the main determinants to select a payment instrument is the *transaction size* (Bagnall et al., 2014 and the references therein). This study reports that 75 % of all payment transactions in seven countries have a size of about 40 euro or less and 50 % have a size of 10 euro or less. This study also reports that people make a payment once or twice a day, as reported in subsection 1.3.1.
Literature on user criteria to any payment channel has been introduced (section 8.1), which includes both cash and non-cash payment systems.

One of the first studies on user criteria to any payment channel reported five criteria (Van Loo et al., 2001): availability (1), acceptance (2), safety (3), anonymity (4) and the transaction amount (5). When it comes to banknote usage, the European Central Bank (2004a) listed also five criteria, being different to those formulated by Van Loo et al., namely convenience (1), authentication (2), efficiency (3), resilience (4) and costs (5). The National Research Council (2007) repeated three criteria for American banknote users: access (1), anonymity (2) and acceptability (3).
These studies show that there is not yet agreement on user criteria or on a uniform terminology. More specific on user criteria of any payment transaction is a Danish publication (Jacobsen et al., 2011) reporting that convenience (1) is found the dominant factor, followed by reliability (2) and costs (3). A similar study by the Bank of Canada (Arango et al., 2012) reports that security (1), ease of use (2) and costs (3) are the most important. A Dutch study on payment behaviour Van der Cruijsen and Van der Horst (2016) discriminates seven user criteria, called attributes: fast (1), safe (2), easy (3), cheap (4), control of expenses (5), provides privacy/anonymous (6) and well-accepted (7). Four of these user criteria are associated more often with cash than with electronic payments, being fast, safe, control of expenses and privacy. In 2014, the first study appeared on *budget control*, focussing on just one user criterion (Hernandez et al., 2014). Paying cash clearly couples purchase and payment to each other, this may contribute to control of spending.

The *transaction time* was not identified in the studies mentioned above, although the Danish study reports 'time' to be a component of convenience. Like the transaction amount, the transaction time seems to be a dominant user criterion. For long the transaction time for cash and non-cash payments was quite similar. Cash payments were reported to be 19 s (Brits and Winder, 2004) and later, in another study 14 s (Snoei et al., 2015). A debit card payment using a PIN-code takes 17 s, a time in-between the two figures reported for a cash payment (Snoei et al., 2015). With the introduction of the technology of *contact less payment* in 2014 the situation changed, as such a payment takes 7 s, significantly lower than a cash payment (Snoei et al. 2015). Contact less payments in the Netherlands are based on Near Field Communication (NFC) and the technology of the chip in the card follows EMV-standards (Europay, Mastercard and Visa).
A further development in the Netherlands will be the introduction of *instant payments* in 2019*,* aiming for the settlement of any electronic payment within 5 s (De Nederlandsche Bank, 2015c).

Based on the provided literature review, an overview of the user criteria identified for *any* payment system is presented in figure 8.7. On the right part of this table these user criteria are applied to *cash*, delivering a map of the pros and cons of cash.

GENERAL USER CRITERIA OF ANY PAYMENT CHANNEL		
User criterion	**Use of cash money by public; coins and banknotes**	
	+	-
1. Access *1.1 Participation* *1.2 Token or account based?*	ATMs available 24/7.	Coins are not 24/7 available. Need a bank account + card.
2. Acceptance *2.1 Range of payments*	General acceptance. Used for person-to-person payment.	Sometimes difficult to spend (e.g. higher denominations). Banknote may become invalid; out of circulation, or no longer exchangeable at central bank.
3. Transaction size	Relative low amounts are paid by cash.	Not enough cash in purse for high transaction sizes.
4. Settlement time	(Immediate transfer).	Time to settle cash transaction is about 20 seconds; contactless about 7 s. Additional time needed to check a suspect note, is it a genuine?
5. Reliability *5.1 Interoperability* *5.2 Direct settlement* *5.3 Back-up* *5.4 Legal tender*	Does not depend on information technology. Immediate transfer. Small amounts. Can always pay with it. Cash is legal tender.	May not have enough in wallet. Risk of loss. Can be counterfeit. Deal earlier accepted in cash. -
6. Ease of use (convenience) *6.1 Opportunity effort* *6.2 Handling* *6.3 Comfort* *6.4 Complexity* *6.5 Ingrained habits* *6.6 Bill sharing*	Provides instant settlement; one handling. Nice to look at (design). Tangible, visible. Easy bill sharing in café/restaurant.	Effort needed to get cash from ATM/bank. Need a wallet, coins may be heavy. Can be dirty. User environment (machines) can be complex and dirty. Bill sharing by app since 2013.
7. Privacy *7.1 Anonymity* *7.2 Imago*	Store of value (hoarding). 100 % anonymity. Payer and payee see each other.	Avoid (VAT) tax payments. Used for money laundering. Used by criminals (e.g. ransom money). Using high denominations or overstuffed wallets is associated with fraud/crime.
8. Security *8.1 Trust*	Visible. No hidden processing. Authenticity check possible.	Loss: pick pocketing, risk of being robbed. Risk on counterfeit.
9. Tariffs *9.1 Private cost* *9.2 Interest rate* *9.3 Pre-paid or post paid* *9.4 Reward programmes*	Fee-free for end users. Increase use at low interest rate. Not prone to negative interest rates. -	Possible ATM fees. No interest compensation. Value decrease in case of high inflation. No reward programmes on use of cash.
10. Self-control *10.1 Budgeting*	Tangible, visible. Less willing to spend; cash payments are more painful than card payments.	No online overviews of expenditures within one period like with cards.

Figure 8.7
Overview of the general user criteria of any payment channel. The priority is set by the author based on the reported importance of criteria mentioned in literature and the perceived frequency that the criterion is referred to. The overview also provides the pros and cons of the usage of cash money.

Individual user criteria are relevant in a user-centric approach and collective user criteria in a society-centric approach, like the social costs of payments (subsection 2.2.1). Kosse (2014) demonstrated that countries characterised by high levels of digitisation have lower social costs of payments. Schmiedel et al. (2012) investigated the social costs of payments in the Euro Area, reporting that countries spend on average about 1 % of their Gross Domestic Product (GDP) on retail payments. The lowest social costs are reported for the Netherlands (0.42 %). The decline of chash brings central banks new challenges. On the one hand they are the suppier of cash, while on the other, they have to supervise the overall policy on socially efficient payment systemstems.

There is a relevant difference between the costs of a cash payment and a digital payment. The variable component of the costs of a cash payment is relatively high, while these are for electronic systems relatively low (Brits and Winder, 2004). On the other hand, the fixed costs of electronic payments are expected to be higher than for cash. When the number of cash payments is decreasing, the variable costs of cash will increase, probably following a non-linear curve, while an increase of digital payments will probably not be of influence on the variable costs and neither on the fixed costs.
There may also be other society-centric considerations that put forward a specific payment system. For example, cash is relatively independent of infra-structure and may therefore act as a fall-back solution to societies, for example when electronic means of payments can no longer be operated, as was experienced by the Japanese in 2011 when there was a major earth quake. Also, the Greek experienced the advantages of cash as a fall-back solution at the top of their debt crisis in 2015. To control capital movements the Greek banks had to close their doors for about three weeks. In this period, the only access to money was to withdraw banknotes via ATMs, which was limited to 60 euro a day per bank account.

In general, suppliers of payment systems develop their products to meet user requirements. In the case of banknotes, the last improvement which was appreciated by cash users goes back to the 1990s, when the popularity of banknotes received a boost because of the large-scale introduction of ATMs. Also, the introduction of euro coins and banknotes in 2002 was appreciated, as it was no longer necessary to change currencies when travelling within the Euro Area. However, improvements on user-friendliness of coins and banknotes remained absent. This inertia in product development, including design, increases the gap with non-cash payments, which are continuously improved on fulfilling user needs.

At the end of this subsection on user criteria, the question arises of what the public will miss when cash will disappear. First, when tangible money like coins and banknotes disappear, the perception of a gift will change. A tip in a restaurant, to a street musician or some money to the piggy bank of a child becomes less visible for both the tip provider as to the receiver.
Changes are also expected on a more abstract level, like mental arrhythmics. Paying 23.67 euro, the payer must do some mental arithmetic during a cash transaction. First, the payer has to be aware of the amount and select the denomination(s) that cover the amount. Subsequently, the change has to be verified. In case of a payment with a denomination of 50 euro, the payer has to check if the change is euro 26.33. In case of a digital payment, the payer must recall the PIN-code instead of some mental arithmetics.
Furthermore, the payer may prefer to keep 10 denominations of 5 euro, instead of one denomination of 50, something which is not possible in case of a digital payment.
Finally, when cash will disappear, people will lose a national identity symbol.

8.3 Applying the Upid-Model to the design of digital payment instruments

Digital payment instruments differ from a banknote. An obvious question is, is it possible to apply the Upid-Model also on digital payment instruments? After all, the users of a banknote and of any other payment instrument have the same aim, the settlement of a payment. A first step is to investigate if the characteristic user functions of a banknote are comparable to the ones of digital payment instruments. There is a variety of digital payment instruments, and two are selected for this exercise, a debit card payment at a retailer, and a payment by a wallet app on a smart phone. Debit cards are frequently used

payment instruments at POS (figure 8.3). A wallet app is a newcomer. Finally, the Upid-Model is applied to a payment with Bitcoins.

8.3.1 Debit card payment at a retailer

Application of the Upid-Model on a payment to a retailer using a debit card, all the Model's user functions can be filled in as done in figure 8.8. Compared to a banknote there is one major difference, the payer interacts with two products, the card and a payment terminal, the reason why figure 8.8 incorporates both. Except for the link to information technology (UXF 6) all User Interface Functions as identified for banknotes are also relevant for a debit card payment. UXF 6 is redundant, as a payment transaction with a debit card is operated within an environment of information technology.

In case of a debit card payment the recognition of the value (UIF 1) is the *amount* to be paid. The 'value' of a debit card is variable, while a banknote's value is fixed. A variable value requires attention in controlled mode (section 5.5), because of the risk of a wrong, perhaps excessive amount. Therefore, retailers may display the amount twice, once on a small screen of the payment terminal, and once on a separate screen behind the cashier, in large characters, usually positioned at eye level. In fact, such a screen becomes part of the hardware of the debit card payment, bringing three products together: debit card (1), payment terminal (2) and a separate screen displaying the purchased goods and the amount to be paid (3).
The handling function of a debit card (UIF 2) shows similarities to the usage of banknotes. Unlike banknotes, all cards have a similar size (subsection 3.3.2). Other cards, like loyalty cards or a driver licence, received the same dimensions. People tend to stack such cards into their wallet, comparable to storing banknotes. In a modern wallet the desired card has to be selected from a range of cards (figure 8.9a), a situation showing similarities to the selection of a banknote in a wallet.
Subsequently, the card has to be inserted into the terminal (figure 8.9b), a handling action also known from banknotes. There is a variety of payment terminals for bankcards and it is not always obvious where to insert the card. In case of contactless payments it is not always clear where to swipe the card (figure 8.9c).
In case of doubt, a banknote should be checked by its public authenticity features (UIF 3). Similarly, a debit card payment has to be authorised, usually by entering a PIN-code in the payment terminal (figure 8.9d); for contactless payments a PIN-code is not required. In case of banknotes, the payer does not have to provide any code.
Authenticity features of banknotes can be unclear to its users, which is comparable to a poor readability of the characters on the key board. The sequence of numbers of the key board is not always the same. People have to search for the right keys, which can be compared to the search for public authenticity features on a banknote.
The communication messages on banknotes (UIF 4) are non-commercial, while such messages on debit cards are often branding messages. Furthermore, the payment terminal sends messages to its users, like 'Welcome', 'Enter PIN-code' and 'Transaction completed'.

In a similar way as people recognise the identity of a banknote (UXF 1), people will experience the identity of a debit card. Receiving a new debit card, they recognise the identity of their issuing organisation and they will also recognise their own identity, like their name and account number. Cards used to be signed personally, although this is often no longer required.
People judge the aesthetics of banknotes (UXF 2) and likewise they will judge the aesthetics of debit cards. Observing the average design quality of bankcards, it seems that the aesthetics of a card should be ranked lower than the aesthetics of an average banknote. Reasons for this seem to be their small size and several obliged standard elements.
Retaining confidence (UXF 3) will probably be ranked higher for debit cards than for banknotes. PIN tracing and skimming has been successfully combatted, by replacing the magnetic stripe by a chip. Logos on bankcards contribute to confidence, quite like a signature on a banknote.

DEBIT CARD PAYMENT AT A RETAILER (card + payment terminal)	
User Interface Functions **UIFs**	**User Experience Functions** **UXFs**
1. Recognising value ***Card**: -* ***Terminal:** The right amount is readable displayed. Often an additional screen is used, which also displays the purchased goods.*	1. Recognising identity ***Card:** When A new card is received: Is it the right bankcard? (Name of bank. Name of person. Correct bank account number.)* ***Terminal:** -*
2. Handling ***Card:** Standardised size.* *Take bankcard out of wallet. Insert card in terminal. During transaction: correct card selected?* ***Terminal:** Different usage situations.*	2. Judging aesthetics ***Card:** Nice to look at contributes to confidence.* ***Terminal:** Well-designed contributes to confidence.*
3. Checking authenticity ***Card:** Free spending up to a low limit (e.g. 25 euro) with contact less verification.* ***Terminal:** Verify PIN. Or biometrics.*	3. Retaining confidence ***Card:** People trust a debit card. Encryption of magnetic stripe, chip.* *Logo: Maestro, Visa, American Express, ...* ***Terminal:** Protected environment (e.g. measure to prevent PIN code fraud by skimming).*
4. Receiving a communication message ***Card:** Branding.* ***Terminal:** Messages from the display (e.g. 'not enough balance', 'press this key', 'do you want a receipt' and 'transaction completed').*	4. Connecting with main image ***Card:** Personal card design possible.* ***Terminal: -***
-	5. Expecting sustainability ***Card:** Durable card. Card can be send to bank for sustainable destruction.* ***Terminal:** Low energy consumption.*
-	6. Linking to a tangible receipt (instead of linking to information technology) ***Card**: -* ***Terminal:** Receipt from transaction.*

Figure 8.8
Application of the Upid-Model to a debit card payment at a POS.

Impression of user functions
Debit card payment

UIF 2 - Handling
Find the right card

a)

UIF 2 - Handling
Entering the card in the payment terminal

b)

c)

UIF 2 - Handling
Contactless payment, where to swipe?

UIF 3 - Checking authenticity
Entering PIN-code

d)

Figure 8.9
Impression of the user functions of POS-payment with a debit card. All images: public domain.
a) UIF 2 - Handling. Wallet stacked with cards. Find the right card in a wallet full of cards.
b) UIF 2 - Handling. Card optimized for inserting in terminal.
c) UIF 2 - Handling. Contactless payment. Where to hold the card?
d) UIF 3 - Checking authenticity. Entering the PIN-code.

A bankcard offers great potential to users interested in 'connecting with the main image' (UXF 4), people may even print their own images on a bankcard (e.g. De Heij, 2012).
Expecting sustainability (UXF 5) is a general user requirement to any payment instrument. Debit cards seem to be more sustainable than banknotes, as they can be used to settle one thousand or more transactions and are usually valid for a period of five years. A broken card is annoying and is replaced against costs, which takes effort and time. Similarly, a damaged banknote can be replaced at a central bank. A payment transaction by a debit card is realised by information technology. A separate User Experience Function of linking to information technology (UXF 6) is therefore not relevant and is replaced by a paper confirmation of the debit card payment. The paper confirmation is delivered by information technology, in this perspective, the reverse situation of a (paper) banknote being verified by IT.

8.3.2 Wallet app payment with a smart phone

The second payment instrument to be investigated is a wallet app on a smart phone. Its user functions can be applied as demonstrated by figure 8.10. Like in case of a debit card payment, all User Interface Functions are relevant for a wallet app payment, except for the banknote's function of linking to information technology (UXF 6), as a payment transaction with a smartphone is a full operation within information technology. Unlike a banknote and a debit card, a wallet app payment does not (yet) make use of 'connecting with main image' (UXF 4). This user function may be filled in with an *artificial host*, as will be elaborated on in section 8.4.

Recognition of the value (UIF 1) is the most important User Interface Function for the payer using a wallet app. Like debit cards, the value is variable, making the readability of the amount key. The screen of a smartphone is small and therefore the readability is often suboptimal (figure 8.11a). Because of digits or commas, problems may occur with setting the right decimals, transferring euro 1,400 instead of 14.
Like a payment with a debit card, a transaction with a wallet app requires several handling actions (UIF 2). First, the payer should take their smartphone and connect to the internet. Users will appreciate that they can make an internet payment 24/7, at any time, and wherever connection to the internet is possible. Once online, the preferred wallet app has to be activated, which may take a moment. Subsequently the user has to register, usually by their username and password or biometry. Next, the address of the payee has to be found or entered. Finally, the amount has to be entered. Mistakes may occur, as the keys on the keyboard of a smart phone are small (figure 8.11b). Corrections may have to be made.
Checking authenticity (UIF 3) is done by entering a user name and a password (figure 8.11c). Alternatives have been developed, mainly biometrics, like authentication by the user's finger. Low amounts may be transferred with a simple code.
Communication messages on wallet apps (UIF 4) are usually branding messages, similar to debit cards. There are also several operating messages like 'username', 'password' and 'send'. Furthermore, the user may add personal messages to the transaction, like "Thanks for the coffee". The app may also offer access to other accounts, bank mail and tasks.
A banknote does not contain personal information like a wallet app. Using a wallet app, people will recognise their own identity and the identity of the payment service provider (UXF 1). Relevant topics are the name of the user, the correct bank account number, and the name of the payee. The identity of the payment service provider is underlined by their name and logo.
Other User Experiences Functions of a wallet app are also relevant to the user, like judging aesthetics (UXF 2). Furthermore, when UXFs are well organised and designed, they will contribute to the confidence in the wallet app (UXF 3), in similar way as a well-designed banknote will contribute to confidence (section 4.4). The IP address (Internet Protocol) for identification of the network interface is usually not shown, although people are advised to do so.
The user's confidence is tested when there is no display, for example in case of a contactless payments using a wristband, (figure 8.11d). The wristband can be brought in contact with a smartphone and transfers can be checked.

Connecting with a main image (UXF 4) seems not yet have been exploited, although the technology is available, like a profile photo on the WhatsApp displays. The logo of the payee could be displayed, if available, once the transactions is cleared.
Wallet apps will probably outperform other means of payments on expecting sustainability (UXF 5). Wallet apps don't produce waist like banknotes or debit cards. Energy consumption of smart phones is low, although attention is required, as the energy consumption of ATM-screens was surprisingly high in a LCA-study of the ECB (subsection 4.6.2).
A banknote is a piece of paper without a link to information technology. A wallet app operates in an IT-environment and, like in case of a debit card payment, the user would like to have a paper confirmation. Wallet apps usually do sent a payment confirmation by email or a notification on the smartphone itself. At home the user may make a printout of the transactions done.

WALLET APP PAYMENT USING A SMART PHONE	
User Interface Functions **UIFs**	**User Experience Functions** **UXFs**
1. Recognising value *The right amount is readable displayed.*	1. Recognising identity *Identity of the user.* *Identity of the payment service provider.*
2. Handling *Any time, any place.* *Activate phone, activate wallet app. Enter username and password. Search for address payee or enter this address. Enter the amount.*	2. Judging aesthetics *Nice to look at (contributes to confidence).*
3. Checking authenticity *Username and password. Or biometrics.*	3. Retaining confidence *Secure internet connection. Safe protocol.* *Well organised (UXFs).*
4. Receiving a communication message *Personal merchandising.* *Separate message that payment is done.* *Additional access to accounts, bank mail, tasks, ...*	4. Connecting with main image *Not yet exploited (profile photo?).*
-	5. Expecting sustainability *No waist. Low energy consumption.*
-	6. Linking to a tangible receipt (instead of linking to information technology) *Print out at home.*

Figure 8.10
Application of the Upid-Model on wallet app payment using a smart phone.

8.3.3 Block chain currencies

A last contribution to the exercise of the applications of the Model for Use-centered Design of Payment Instruments on a digital payment instruments concerns block chain currencies. The first and best known is the Bitcoin, which has been introduced in subsection 2.4.1. It seems that the Model for banknotes can also provide insights on the use of digital currencies. The use of the Bitcoin is well reflected by an advertisement of a provider of wallets for Bitcoins, telling: “Your own Bitcoins, on your own phone!” (figure 8.12). All User Interface Functions of the Model for banknotes return when a payment is made from a Bitcoin wallet. A remarkable difference between national currencies and a Bitcoin is the use of the decimal point, an aspect of value recognition (UIF 1), which is for Bitcoin eight decimal places instead of the regular two (subsection 3.2.1).
The handling of Bitcoins (UIF 2) is like handling any other currency in a wallet app, which shows similarities to the handling of banknotes (subsection 8.2.2).

The innovation of Bitcoins is mainly an innovation on checking authenticity (UIF 3). Instead of authenticity features or a PIN-code, an authenticity check is done by *mining*. Mining is the process of adding transaction records to Bitcoin's public ledger of past transactions, called the *block chain*. The block chain is used to distinguish legitimate Bitcoin transactions from attempts to re-spend coins that have already been spent elsewhere. Summarised, Bitcoin is a *distributed ledger technology*, based on public input.
The communication themes of a Bitcoin transaction (UIF 4) are mainly branding messages of the provider of the wallet, similar to other wallet apps.

To start the Bitcoin, a first block was created on 3 January 2009, known as the *genesis block.* This was a single transaction paying 50 Bitcoin to its creator, Satoshi Nakamoto (2008). However, Bitcoin is indistinct about its creator; it is still unknown who he or she is and there are still speculations going on about Nakamoto's identity (UXF 1). Obviously, quite different from the clear identity of the issuers of banknotes. Wallets for Bitcoin are provided online and follow similar identity policies as other wallet app providers (subsection 8.3.2).
Although the Bitcoins are invisible, attractive interface design of Bitcoin wallets (UXF 2) will be appreciated.
Confidence in Bitcoin (UXF 3) is confidence in the distributed ledger technology. The fact that everyone can be a miner probably contributes to the user's confidence.
The currency symbol of the Bitcoin is the letter B with two vertical stripes and there are several variants (figure 2.6i, figure 8.12). The currency symbol connects people to the Bitcoin and serves as a main image (UXF 4).
Whether a Bitcoin is a sustainable currency (UXF 5) is a question. For each transaction, the involved Personal Computers (PCs) receive a copy of the database, requiring significant memory capacity on the hard discs. The electricity necessary to run these PCs leads to high energy consumption for a single Bitcoin transaction.
From all digital means of payments, the Bitcoin seems to be the most advanced when it comes to the application of information technology (UXF 6).

8.4 Lessons learned from use-centered design of banknotes

The previous investigated whether the Upid-Model can also be applied to other means of payments than a banknote (section 8.3). As far as the explorations have been made, this seems to be possible. Since this is possible, this section explores whether use-centered design advices for banknotes are also applicable for the design of digital means of payments.
Banknote designers are often graphical designers, while the designers of digital means of payment are often User Experience Designers (UXD), as introduced in subsection 2.2.2. This thesis already advocated that banknote designers may learn from UXD-designers. And indeed, UXD-designers may learn from banknote designers.
Knowledge on the human visual system with respect to banknotes (chapter 5), is also applicable to digital payment instruments. One of the complications of banknotes is that users are distracted from the relevant user function mode; they are jam-packed with all type of features (subsections 3.4.3 and 5.4.5). Similarly, focussing on the amount to be paid, users of digital payment instruments should not be distracted by other design elements.

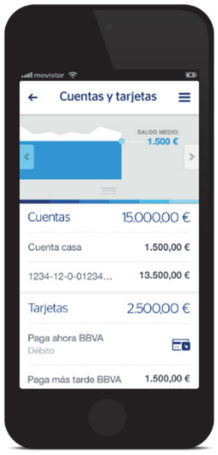
Once more, the identified user functions of the Model for Use-centered Design of Payment Instruments are taken as a guide. An exhaustive list is outside the scope of this thesis, merely some relationships and/or examples are provided for each user function.
The design advices on the readability of banknote numerals (subsection 3.2.2) are relevant for the readability of displays of payment terminals or smart phones (typefaces, character height, contrast, the use of colours etcetera). Figure 8.13a shows an example of the screen of a wallet app using light characters on a dark background (like figure 3.3b), where most screens display dark characters on a light background (like figure 3.3a). Within an IT-environment people could set their own preferences for fonts.

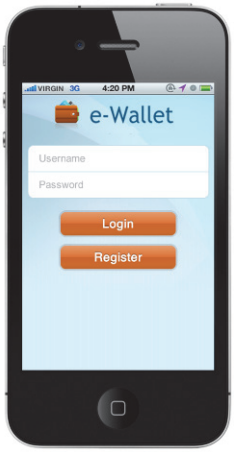
Impression of user functions
Payment app on smart phone

UIF 1 - Recognising value
Poor readability of amounts

UIF 3 - Checking authenticity
Enter username and password

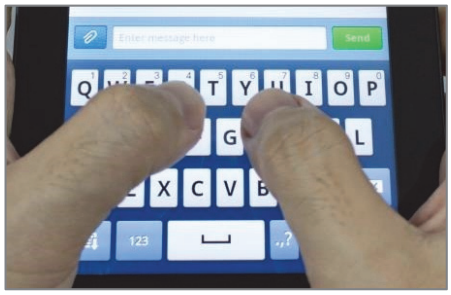
a)





c)

b)



d)

UIF 2 - Handling
Small keyboard on smart phone

UXF 3 - Retaining confidence
Contactless payment with wristband

Figure 8.11
Impression of the user functions of wallet app on a smart phone. All images: public domain.
a) UIF 1 - Recognising value. Poor readability of amounts. Currency symbol € behind the amount with spacing.
b) UIF 2 - Handling. Small keys on keyboard of smart phone.
c) UIF 3 - Checking authenticity. Enter username and password.
d) UXF 3 - Checking confidence. Contactless payment using a wristband. The wristband can be brought in contact with a smartphone.

Advertisement for a wallet app for Bitcoins

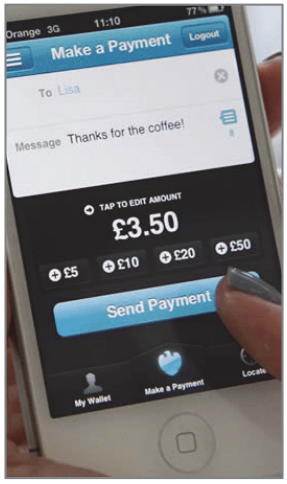
Figure 8.12
Advertisement for a wallet app for Bitcoins (2016). Image: public domain.

The designers of digital means of payments, most likely UX-designers (subsection 2.2.2), should list the relevant user requirements for checking the amount to be paid, similar to the setting of the user requirements for denominating a banknote.
A textbook example is provided by the Rabobank in 2012, aiming for a more user-friendly bankcard. The orientation of the card was changed from a horizontal to a vertical orientation (UIF 2), corresponding with the vertical insertion of debit cards with a chip into a payment terminal (figure 8.13b). Further improvements are found in the sequence of the personalised texts (UXF 1). On the first line, the full account number was printed, the International Banking Account Number (IBAN), followed by the name of the card holder on the second line. This information is kept readable when the card is inserted in a device necessary to connect to internet banking. Furthermore, the expiry date moved from the front to the reverse, close to the field for the signature (UXF 3).

Observing the handling functions of a bankcard, like holding and inserting, there are several similarities identified with banknote design (UIF 2). Most people are right handed and crucial information should not be covered by the hand when using a card. With respect to health and safety, there are also similarities between a debit card and a banknote; people may hold a debit card for a moment between their teeth or lips.

Impression similar design functions of digital payment instruments and banknotes

UIF 1 - Recognising value
Negative numerals



a)

UIF 2 - Handling
Portrait orientation

b)

UXF 3 - Retaining confidence
Signature

c)

UXF 4 - Connecting with main image
Artificial host on app

d)

Figure 8.13
Impression of the design of digital payment instruments in relation to banknote design. All images: public domain.
a) UIF 1 - Recognising value. White numeral on dark background or dark numeral on white background? Currency symbol £ in front of the amount without spacing. Note the personal message: “Thanks for the coffee!” (UIF 4).
b) UIF 2 - Handling. Vertical format of debit card to assist user inserting card in payment terminal, introduced in 2012.
c) UXF 3 - Retaining confidence. Well-known names and logos support the confidence in the card, similar to a signature on a banknote.
d) UXF 4 - Connecting with main image. Artificial host “Evi van Lanschot” part of apps launched by Van Lanschot Bankers (2015). Note that the face has no eyes or nose.

Like banknotes, debit cards may carry public authenticity features (UIF 3). Well known is the hologram with the dove on the Visa credit cards, in 1984 the first in its kind. Meanwhile, holograms and colour shifting inks disappeared from modern banking cards, which show fewer public authenticity features. This development can be seen as a shift towards confidence, from UIF 3 to UXF 3, as described for banknotes (subsection 4.4.4). People have difficulties with the recall of authenticity features on banknotes. Similarly, people may not be able to recall their PIN-code, user name or password.

Communications themes on banknotes (UIF 4) distract the user from its primary user functions (section 2.8). Such messages were introduced around 1850, with the arrival of the Prosperity period (subsection 1.3.3). Learning from banknotes, the main user function(s) should be the message. Digital payment instruments don't include, to date, non-relevant communication themes.
Banknotes are seen as nation branding, while digital means of payments are dominated by a corporate identity, especially by name, logo and colours (UXF 1). Identity topics as discussed for banknotes could be transferred to digital means of payments, like the use of an identity description and positioning diagrams (subsection 4.2.3).
An independent graphic designer, like contracted for banknote design, may deliver digital payment instruments which will be judged by their user as being more beautiful (UXF 2).
Issuers of digital payment instruments may introduce longitudinal measurements on the aesthetics of their products (section 6.7).
Confidence features of banknotes (UXF 3) are also found on digital payment instruments, like a number and a logo, serving as a signature (figure 8.13c). The number of the credit card is often printed in relief, adding tactility, similar as the relief of the gravure on a banknote. However, this relief printing is used for making a copy for the payee and is less-and-less practised.
When it comes to confidence, digital payment instruments seem to rely more on confidence features than banknotes do.

People like to look at images of other people, one of the reasons for a portrait on a banknote (subsection 5.4.4). People may also connect to other main images, like an animal, flower or a building (UXF 4). No such images are found on digital means of payments. An early example of an artificial host with human properties introduced within payment apps is "Evi van Lanschot" for Van Lanschot Bankers, shown in figure 8.13d. Note that this female character does have a mouth, but no eyes or nose.
When it comes to 'green digital payment instruments' user requirements will be similar as for green banknotes. Therefore, user requirements for banknotes on UXF 5 will, in general, also be applicable to digital means of payments.
Digital payment instruments operate within an environment dominated by information technology. Therefore, there is no explicit user function of linking to information technology. Instead, users of digital means of payment would like to receive a paper confirmation or like to have access to such a notification.
QR-codes are already used for digital means of payments, but only to a limited extent on banknotes (subsection 4.7.5).

8.4 Conclusions on applying the Upid-Model to digital payment instruments

Cash is losing market share, although it is not expected that coins and banknotes will disappear within the coming decade. Cash has several advantages over other means of payments, like being anonymous, tangible and may assist budget control. Cash may also serve as a fall back to the public and to retailers in case digital systems fail.
However, the image of cash is under pressure. People opt for digital payment instruments as they fulfil their user needs better. Cash cannot provide the dynamic look of paying with a smartphone.
Most likely, the upper class are the first to abandon banknotes, the same who were around 1850 the first to adopt the wider use of banknotes. Nationally, the Swedes were the first to have banknotes and the Swedes are perhaps also the first to abolish them.

Access and acceptance are the two main user criteria for the selection of a payment channel. The transaction time needed to settle a payment is most likely the third criterion. Currently, cash is losing user preferences on these three main user criteria. The pros and cons of the use of cash are mainly independent of the design of coins and banknotes, and therefore a use-centered design of banknotes will probably not counteract the developments described.

The Upid-Model has been successfully applied to two digital payment instruments, a debit card payment at a POS and an internet payment with a wallet app on a smart phone. In addition, a first exploration has been carried out to investigate whether the Upid-Model can also be applied to a Bitcoin, a currency based on block chain technology. Application of the Upid-Model on digital payment instruments requires associative thinking, as the design concept of a specific user function of a digital payment instrument is often completely different than applied for banknotes, although the user function itself is similar.

When the Upid-Model is applied to digital payment instruments, it may be assumed that there will be similarities between digital payment instrument A, B or C. Furthermore, the economic functions of money remain valid and the person using a payment instrument can be seen as a constant. People do not change because of the use of a payment instrument, although people may have a preference for a specific payment instrument, when it matches better to their user criteria.
Comparing a banknote payment with digital payment instruments, it seems that a banknote payment requires less handling actions (UIF 2). Connecting to a main image (UXF 4) is absent for digital payment instruments or delivers a concept which is rather different from banknotes, like an artificial host on wallet apps. Although evident, the most obvious difference between banknotes and digital payment instruments is the user need to receive a confirmation of a payment done, like a tangible paper receipt or a separate electronic confirmation. In case of a payment with banknotes there is no need for such a confirmation.

Application of the Upid-Model on digital payment instruments did not unveil other user functions as applicable for banknotes. However, there is one topic which could not be addressed, the user need for *reliability*. When a digital transaction is interrupted, payer and receiver, become uncertain an irritations may occur. Unlike a cash transaction, a digital payment may fail on one or more of the following three conditions. First, there is the condition of the availability of electricity, either by the power grid in case of a debit card payment, or by a battery in case of payment by smartphone. A second condition is access to the internet, followed by a connection to the payment service provider, usually a bank. Third, there should be a sufficient amount of money on a person's account.

Most of the given design advices on how banknotes can be made more user-friendly are also applicable to digital payment instruments. This is largely explained by the observation that the design of digital means of payments is characterised by a technology-driven design approach. Apparently, the end users first have to complain before the design of UIFs or UXFs will be adapted. The author's advice to both banknote designers and designers of other payment instruments is to deliver a use-centered design.

You can fool all the people some of the time, and some of the people all the time, but you cannot fool all the people all the time.
Abraham Lincoln (1809 - 1865)

CHAPTER 9
CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

9.1 Introduction

Four research questions are posted in section 1.4 and all four received a positive answer:

1. *1. Is it possible to develop a Model for Use-centered Design of Payment Instruments, the Upid-Model, which can be applied to banknote design?*

As all user situations concerning banknotes could be addressed, the Upid-Model proved to be an appropriate description of the reality.
Furthermore, the Upid-Model provided insights in the interrelationships between the different user functions.

2. *Does the Upid-Model deliver an appropriate framework to report measurements reflecting the users' perspective?*

The Upid-Model proved to be an appropriate framework to report on (existing) measurements on the opinions of the public.

3. *Is the Upid-Model an appropriate model to underpin the design of a new banknote?*

The Upid-Model proved to be a useful guide to create a use-centered banknote design, delivering a novel concept.

4. *Can the Upid-Model also be applied to digital payment instruments?*

The Upid-Model is applicable to digital means of payments, in case a debit card and a wallet app.

Being the first thesis on A Model for Use-centered Design of Payment Instruments, applied to a banknote, there are several discussion topics.
In the section recommendations suggestions are made to develop the Upid-Model further.
This final chapter presents the main conclusions (section 9.2), discussion topics (section 9.3) and recommendations and guidelines (section 9.4).

9.2 Conclusions

Academic model building on banknote design is at its infancy. The advocated route is the introduction of a use-centered design policy. Banknote designs following a complete use-centered design approach could not be identified and the novel Upid-Model offers a start. This Model divides the banknote's user functions into User Interface Function (UIFs) and User Experience Functions (UXFs). Four UIFs have been identified and six UIFs.
As the Model is transferable and verifiable, it is an academic model and provides a sound basis for use-centered banknote designs. Furthermore, the Upid-Model provided a terminology to address design topics of payment instruments, the part of it that people have in their hands. The Model also proves to be a framework to assess a banknote design on its user functions. Moreover, the Upid-Model is connected to other academic knowledge domains like economics, more specifically to the economic functions of money, to use-centered design and to interaction design.

The following lists the ten main conclusions of this thesis:

1. The future of banknotes

The transition of a cash society to an electronic payments society does not yet imply that cash will disappear. In the Netherlands, cash payments account for less than half of all POS-payments, while credit card payments cover about 3 % of all POS-payments and are not expected to disappear. At the end of the day, the question will be whether society is willing to bear the social costs of low cash volumes. Predictions at which level cash payments may decline are not (yet) made. One of the basic research questions is at which level retailers will no longer accept cash; what are the tipping points and which are the retailers' criteria?

2. Use-centered design methods for banknotes are unknown

Central banks are unaware of use-centered design methods and as a consequence such methods are not applied in banknote design. Unawareness is explained by the fact that there is no discourse on banknote design; academic publications on design policies for banknotes are not available. Furthermore, central banks are no design agencies and the preparation of a banknote design is an unusual activity, which comes along once every 10 to 15 years. Banknote design activities will meet resistance of the conservative and risk avoiding corporate culture of a central bank. There are many publications on banknote design, mainly providing anecdotal information, focussing on the banknote's main image (UXF 4).

3. Improving user-friendliness

Improvements of banknotes on user friendliness find their origin in one or more UIFs and/or UXFs.

4. People operate banknotes in UIF 1 and M1

The most decisive variable within a use-centered banknote design is UIF 1, the recognition of the banknote's value. Most people accept banknotes without any hesitation, their brains operate in automatic mode and the just received banknote is perceived in full image mode. In terms of the Model for Use-centered Design of Payment Instruments people operate banknotes in UIF 1 and its perception is in M1, following the 4M Model for the Perception of Banknotes. In general, people have no interest in any of the other banknote's user functions when they settle a payment.

5. Optimise banknotes on User Function Modes

A User Function Mode describes the situation of a specific user group operating a specific user function. To serve UIF 1, banknotes should have *denomination features,* which are divided in features for colour blind, poor sighted and blind. Normally sighted will use similar features as for the visually impaired.
Handling features will serve UIF 2, which can be different for the general public and for retailers.
Authenticity features serve UIF 3 and are split in public and retail features, to be either used with a machine or not.
Communication features are part of UIF 4.
Likewise, *identity features* serve UXF 1 and *confidence features* serve UXF 3. Specific features for aesthetics (UXF 2) are not identified. A main *image feature* will serve UXF 4, *sustainable features* aim for UXF 5 and *IT-features* are part of UXF 6.

6. Implementation of use-centered design

Present banknote designs are biased by a technology-driven approach. When banknotes are designed along a use-centered design policy, they will receive higher scores on all user functions, so is the expectation. Implementation of a use-centered approach will immediately deliver results, especially in the field of the two main User Interface Functions of a banknote, UIF 1 and UIF 2.
Introducing a use-centered design policy is probably not enough to reverse the transition of cash money to digital payments, as electronic means of payments satisfy user needs on higher service levels, like transaction time and ease of use. Digital payment instruments may also outperform cash on other user functions like handling (UIF 2), especially contactless payments.

7. Usability and experience-ability scores

The Upid-Model serves as a framework to report measurements which reflect the users' interest. For each user function measurements have been carried out on existing banknote models. The measurement scores of each user functions can be combined to one score, like a usability score representing all UIFs and an experience- ability score for all UXFs. Although not yet done, a similar approach can be applied to other payment instruments. One of the first research subjects were cash and digital means of payments go together is Lifecycle Analysis (LCA), a topic within the user function of requiring sustainability (UXF 5).

8. Main user functions are out of focus

Banknote designers often neglect the design of value recognition (UIF 1) and handling (UIF 2), the two most relevant User Interface Functions. Central banks tend to set their priorities on an authenticity self-check (UIF 3) and a communication message (UIF 4). However, people do not use banknotes to check their authenticity. Neither do they use banknotes because of its communication message(s). Furthermore, banknote designers seem to move away from UIFs and tend to zoom in on UXFs like reacting on the main image (UXF 4). However, once a new banknote design is issued, people tend to forget about the communication messages (UIF 4 and UXF 4). As a result, people have to undergo the sub-optimal designed UIFs during each cash payment.
Summarising:

1) The usability score of banknotes is low; UIFs are residual design items.
2) Banknote designers are too much focused on UXFs.
3) After introduction UXFs are no longer key.

9. Model for banknotes also applicable for digital means of payments

The user functions identified within the Upid-Model for banknotes are also applicable to digital means of payments.
Furthermore, it is expected that the approach of dividing user functions into UIFs and UXFs is also applicable to other utility products such as, but not limited to, tax forms, passports, letter boxes, park benches, traffic lights and bridges.

10. Suggestions for use-centered banknote design

Figure 9.1 lists the main conclusions for each of the ten identified user functions.
An Upid-Model-based checklist of user requirements of banknotes is provided in Appendix 2.

TEN SUGGESTIONS FOR USE-CENTERED BANKNOTE DESIGN			
UIF	1	Recognising value	Bright colours running to the edge, large numerals and discriminating main images.
	2	Handling	A horizontal front combined with a vertical reverse, respectively suitable for use in people's wallet and in retail drawers/banknote acceptors.
	3	Checking authenticity	Focus on retailer instead of public; retail features on the reverse. Three public features, all on the front. Self-explaining, intuitive approach. Feature plus an attractive priced detector.
	4	Receiving a communication message	One main theme. Non-directive message, based on emotion.
UXF	5	Recognising identity	Identity description on half A4-page by top management, based on user preferences.
	6	Judging aesthetics	High aesthetics supports trust.
	7	Retaining confidence	New banknote designs; no upgrades. Keep one foot in the past.
	8	Connecting with main image	Implement positive emotions like 'pleasant surprise'.
	9	Expecting sustainability	Opt for sustainable banknotes. No environmental burden, ethical labour conditions. Durable banknotes. Clean note policy adjusted to the public.
	10	Linking to information technology	Link banknote to smartphone. Include a QR-code. Banknote numbers on the front.

Figure 9.1
Ten suggestions for use-centered banknote design.

9.3 Discussion

The title of this thesis is "A Model for Use-centered Design of Payment Instruments Applied to Banknotes: Upid-Model", which suggests that there are more models that could serve a use-centered banknote design policy. The Upid-Model is an encompassing model and therefore discussions on other models will, most likely, turn out to be subparts of Upid; other models could not be imagined, as the Model takes user behaviour with banknotes as a starting point. When the stakeholders (subsection 1.3.1) were to be taken as a starting point for model building, other models could be developed. A suggestion for a model to organise machine readable security features is proposed by Balke (2017).

Two parameters, use and experience, are the foundation of the developed Model. Why these two? Why not usability and aesthetics? And why not three, like low social costs (1), sustainability (2) and beauty (3)?
Two parameters fit better with the aim of the smallest testable model (section 1.1) is a first answer. Second, architects and artists often explain their work in the light of use and experience. This split in two views, matches with the practice of screen designs for information technology, discriminating User Interface Design and User Experience Design.

This dissertation proposes four User Interface Functions and six User Experience Functions, bringing a total of ten user functions. This triggers the question of the completeness of the Upid-Model, are all user functions identified? The Upid-Model has been presented at several occasions on relevant seminars, under the preliminary name of Coaster-Model, and have also been published, which did not give rise to any response. Experts in the field of banknote design did not come up with additional user functions, after they were invited to bring such suggestions forward. Specifically asked in 2013, the Dutch public did not bring any other UIFs forward either.

One more question on the Upid-Model concerns the ranking of the user functions. Within the Model different banknote design policies are composed by setting different priorities of UIFs and/or UXFs. Ranking of the UIFs has been validated once, in the Netherlands in 2013. The proposed ranking of the UXFs has not been validated.
Another topic of discussion is the relation between user functions. Independent user functions are preferred, which seems to be the case for the user functions proposed. However, some user functions relate to each other, for example the user functions contributing to 'communication of the full banknote', involving UIF 4, UXF 1 and UXF 4, respectively representing 'receiving a communication message', 'experiencing identity' and 'connecting with the main image'. These three user functions could be replaced by one user function covering the 'reception of the total message of a banknote'. However, all these three user functions are found relevant to use-centered banknote design; such an intervention would simplify the Model too much.

Emotions are part of judging aesthetics (UXF 2) and the communication message (UIF 4), so is the assumption. However, emotions may also be seen as part of experiencing identity (UXF 1) and reacting on the main image (UXF 4).
For the user function 'judging aesthetics' (UXF 2) no *aesthetic features* have been identified, while such usage features could be listed for all other user functions. Does this imply that the aesthetics is not a user function like the other user functions of the Upid-Model? This question remains unanswered.
Banknotes carry main images and therefore the user function 'reacting on the main image' (UXF 4) is made part of the Upid-Model. When main images would disappear, there would no longer be a rationale for UXF 4 and this user function should be eliminated from the Model. Also, digital payment instruments do, in general, not display any main images.
Within the Upid-Model health and safety aspects are part of the handling function (UIF 2). People expect banknotes to be covered for health and safety aspects, they are seen like hygiene factors. However, one may question this view and argue that health and safety issues are a separate user function.

The Upid-Model is applied as a framework to report measurements that reflect the banknote users' perspective and the following discussion topics are raised. One may question whether recall is a representative test situation, as people will receive visual and tactile stimuli when they handle banknotes. Other measurement methods for the user functions may lead to other measurement scores. In turn, they will influence the aggregated user function scores, like usability scores (all UIFs) and experience-ability scores (all UXFs).
Measurement scores from different countries may only be compared with each other when the studies have a similar set up. Usually, study set ups differ from each other, like in case of the studies reporting on respondents being unable to mention one single authenticity feature. On the other hand, the presented figures all point in the same direction; all studies report that there is a large group unable to mention a single feature.
The Upid-Model is also proposed to be an appropriate tool to underpin the design of a banknote. One may question this approach by arguing that an optimal design concept for a single user function will be similar all over the world and as a result all currencies will receive similar designs. However, similar design concepts for specific user functions does not have to lead to identical banknote designs. First, central banks and their banknote designers are free in theme and subtheme selection and also in the selection of authenticity features. Second, central banks may set different priorities to the banknote's user functions within the Upid-Model. Furthermore, banknote designers will have their own design philosophy to fill in the graphical lay-out and the application of colours.
The Upid-Model has been applied to two digital means of payments. These two exercises, and a small exercise on a payment with a Bitcoin, suggest that the Upid-Model is also applicable to other means of payments. However, this issue requires more study.

9.4 Recommendations and guidelines

The presented study is the first on use-centered design of banknote design and will therefore trigger several recommendations. The most relevant ones are reported.
Measurement methods are available for several user functions, but not for all. A first recommendation is therefore to develop a measurement method for each user function. Preferably such a method be longitudinal, as it will indicate trends. Longitudinal measurement methods are successfully applied for handling (UIF 2), an authenticity self-check (UIF 3), judging aesthetics (UXF 2), experiencing confidence (UXF 3) and neatness of banknotes (UXF 5).

Banknote designs can made more user-friendly by:
- Analysing existing banknote designs on all user functions, focussing on problems experienced by the users,
- Extension and completion of literature on all banknote's user functions,
- Detailed determination of user requirements,
- User research to fill in the 'blanks' of user requirements,
- Quantitative ranking of UXFs,
- Setting criteria for Corporate Social Responsibilities.

The main user of banknotes is the public. The most relevant topics to the public are mapped as “Ten Guidelines for Use-Centered Design of Banknotes” and assist central banks to make a start with a shift from a technology-driven banknote design policy towards a use-centered one. The presentation of these guidelines concludes this thesis.

Guidelines for Use-centered Design of Banknotes

1. Be reluctant to replace existing banknotes

People have a wait-and-see attitude towards new banknote designs. New banknotes are first of all there for the counterfeiter, so is their view.

2. Design user friendly banknotes

Banknotes are issued for the public and not for stakeholders.
User friendly banknotes are the result of a use-centered banknote design policy. Technology should serve the banknote design and should not prevail.

3. Opt for new instead of an upgrade

A new design will receive attention and will not be confused with the old model. A completely new banknote design will overwrite existing memory paths.

4. Provide an appealing identity

A new banknote is there for the coming decade. In times of self-acting citizens with personal responsibilities, traditional symbolism is experienced as paternalism. Introduce forward looking symbolism, evoking a little smile.
Prepare an identity description, a short text of about half an A4.

5. Offer one main theme

People use banknotes to pay with and not for its communication messages.
According to the linguistic determinism people can only remember something when they can give a name to it.
To reduce the memory load, a series of banknote should cover one main theme and each denomination should tell one story.

6. Focus on value recognition

What people need most from a banknote is instant value recognition. Colour is the main design parameter, already recognised when the banknote is handed over. Seeing just a small part of it, people recognise the banknote's value first by its colour,
A characteristic main image and large numerals are two more parameters contributing to the denominating process. The banknote's dimensions play a minor role.

7. Optimise the colour scheme

Make sure that the colours of a new banknote fit in the colour scheme. Changing a banknote's colour should be verified by the colour-blind and the poor sighted.

8. Optimise handling

Make sure banknotes fit properly into a wallet.
Assign the front to the public and the back to retailers and banknote automates. The interaction between humans and machines accepting banknotes - receive and pay - is increasing.
A single note height serves machines and automated processing of banknotes best.

9. Underline confidence

People want to trust banknotes and they can. Banknotes from ATMs are genuine and checking banknotes with automatic devices by retailers is on the rise. Confidence features will support confidence, just as aesthetic pleasing banknotes.

10. Offer an authenticity self-check

People should be able to do an authenticity self-check. Three public features are sufficient.
Features should be self-explaining, intuitive. Use realistic images and easy names which fit the theme. Within three seconds a feature should bring a yes-no decision and an unambiguous operation.
Features should be based on feel and look-at. Be reluctant with tilt features, especially with colour changing features.

REFERENCES

A

Abrams, R.K. (1995). *The Design and Printing of Bank Notes: Considerations When Introducing a New Currency.* IMF Working Paper. WP/95/26. International Monetary Fund. Washington.

Albers, J. (2001). *Van ontwerp tot biljet: DNB begeleidde het euro 200 biljet.* (From design to banknote: DNB managed the euro 200 note). De Florijn. Special: Euro Echtheidskenmerken. 3(14). De Nederlandsche Bank NV. Amsterdam.

Allen, J.M. and Straub, A.L. (1956). *Sign brightness and legibility.* Virginia Council of Highway Investigations and Research. Reprint 16. Reported in: McCormick, E.J. (1970). *Human Factors Engineering.* Third Edition McGraw-Hill Book Company. New York.

Allen, K. (2017). *Bank of England considers palm oil for £20 polymer notes.* The Guardian.

Allegre Rabiela, A. (2016). New Series of Mexican Bankotes. Challenges for design and communication. IBDA Insight, 12, 24-29.

Alter, A.L. and Oppenheimer, D.M. (2008). *Easy on the Mind, Easy on the Wallet: The Roles of familiarity and Processing Fluency in Valuation Judgements.* Princeton University.

Andersen, G. (1975). *Banknotes: principles and aesthetics in security graphics.* Danmarks Nationalbank. Copenhagen.

Anholt, S. (2007). *Competitive Identity: the new brand management for nations, cities and regions.* Palgrave Macmillan.

American Foundation for Blind Vision (2009). www.afb.org.

Argo, J.J., Dahl, D.W., Morales, C.A. (2006). *Consumer Contamination: How Consumers React to Products Touched by Others.* Journal of Marketing, 70, 81-94.

Arango, C., Hogg, D. and Lee, A. (2012). *Why is Cash (Still) So Entrenched? Insights from the Bank of Canada's 2009 Methods-of-Payment Survey.* Bank of Canada. Ottowa.

Arthur, P. and Passini, R. (1992). *Wayfinding-People, Signs, and Architecture.* McGraw-Hill. New York.

Asch, S.E. (1946). *Forming impressions of personality.* Journal of Abnormal and Social Psychology, 41, 258-290

Atkinson, C. (2003). *New Hollywood star: the $20 bill.* Advertising Age, 74(3), 3.

B

Bagnall, J., Bounie, D., Huynh, K.P., Kosse, A., Schmidt, T. Schuh, S. and Stix, H. (2014). *Consumer Cash Usage: A Cross-Country Comparison with Payment Diary Survey Data.* Working Paper No. 1685. European Central Bank. Frankfurt.
Also published as Working Paper No. 422 by De Nederlandsche Bank NV. Amsterdam.

Balke, P. (2017). *Introducing Machine Readable Security Features - Selection Criteria.* Currency News, 15(2), 10-11. Sunbury. Also available on http://www.dnb.nl/en/news/dnb-publications/dnb-payments/index.jsp

Balke, P. (2011). *From fit to unfit: How banknotes become soiled.* De Nederlandsche Bank NV. Presented at Watermark Conference 2011. Rostov-on-Don.

Balodis, E., Firth, A., Smilek, D. and Malcolmson, K. (2010). *A Method for Quantitatively Determining the Security Effectiveness of Bank Note Security Features and Whole Notes.* Bank of Canada and University of Waterloo. Conference on Optical Security and Counterfeit Deterrence. San Francisco.

Balodis, E. (2012). *Research into Banknote Circulation Wear: Cash Handling Habits of Canadians.* Conference on Optical Security and Counterfeit Deterrence. San Francisco.

Banco Central de Chile (2009). *Iconografia de Monedas y Billetes Chilenos.* (Iconography of Chilean Banknotes). Banco Central de Chile. Santiago.

Banca d'Italia (2014). *Premio per la scuola 2013/2014. Inventiamo una banconota.Catalogo della mostra.* (Award for the school year 2013/2014. Invent a banknote. Catalogue of the exhibition.). Banca d'Italia. Rome.

Banco de España (2004). *Spanish Banknotes 1940 - 2001.* Banco de España. Madrid.

Banco de México (2014). *Market research by the Banco de México cash department.* Billetaria, 16, 17-19.

Banco de México (2015). *Indicators of public perception of banknotes (yearly average of quarterly data).* http://www.banxico.org.mxsultar.

Banknote Ethics Initiative (2013). http://www.bnei.com.

Bank of Canada (2017). *The Bank Note Confidence Index - 2017 results*. Ottawa.

Bank of Canada (2016). *Bank of Canada launches public consultation to select Canadian woman to be on next series bank note.* Press Release. Bank of Canada. Ottowa.

Bank of Canada (2014). *Bank of Canada invites Canadians to comment on bank note design principles.* Press release. Ottawa.

Bank of Canada (2012). *Statement by Governor Mark Carney on the $100 Bank Note.* Press release. Ottowa.

Bank of Canada (2009). *The Bank Note Confidence Survey.* Ottowa.

Bank of Canada (1982). *Possible approaches to making banknote denominations distinguishable by the blind and visually impaired.* Bank of Canada Review. Ottowa.

Bank of England (2017). *A brief history of banknotes.* http://www.bankofengland.co.uk/banknotes.

Bank of England (2016).*Polymer banknotes. Q&A library.* http://www.bankofengland.co.uk/banknotes.

Bank of England (2013). *Names suggested by the public for use on Bank of England banknotes.* http://www.bankofengland.co.uk/banknotes.

Bank of Israel (1999). *The New Banknotes of Israel.* Brochure. Jerusalem.

Bank of Japan (2004). *Security Features of the New Bank of Japan Notes.* https://www.boj.or.jp/en/note_tfjgs/note/security/bnnew3.htm/#p03

Bankwet (1948). *Wet van 23 April 1948.* Staatsblad no. I 166. Den Haag.

Beck, K. Grenning, J., Martin, R.C., Beedle, M., Highsmith, J. Mellor, S. Van Bennekum, Hunt, A., Schwaber, K., Cockburn, A., Jeffries, R. Sutherland, J. Cunningham, W., Kern, J., Thomas, D. Fowler, M. Marick, B. (2001). *Manifesto for Agile Software Development.* Agile Alliance. http://agilemanifesto.org.

Bender, K.W. (2004). *Geldmacher, das geheimste Gewerbe der Welt*. (Moneymakers: The Secret World of Banknote Printing, 2006). J. Wiley-VCH. Weinheim.
Benítez, A., Alcalde, I. and Darío Negueruela, J. (2014). *The use of surveys by central banks.* Billetaria, 16, 34-36
Beyer, H., Holtzblatt, K. (1998). *Contextual Design: defining customer-centered systems.* Morgan Kaufmann. San Francisco.
Bloch, P.H., Brunel, F.F and Arnold T.J. (2003). *Individual Differences in the Centrality of Visual Product Aesthetics: Concept and Measurement.* Journal of Consumer Research, 29, 551-565.
Bloom, M.T. (1953). *The Man Who Stole Portugal.* Scribner. New York.
Bloom, M. T. (1982). *Money of Their Own: the True Story of the World's Greatest Counterfeiters.* BNR Press, Port Clinton, Ohio, 1982
Bloom, M. T. (1983). *The Brotherhood of Money. The Secret World of Banknote Printers.* BNR Press, Port Clinton, Ohio.
Boersema, T. (2006). *Comprehensibility of graphical symbols for clarifying security features.* In: De Waard, D., Brookhuis, K.A. and Toffetti, A. (Editors): Developments in Human Factors and Transportation, Design, and Evaluation. Shaker Publishing. Maastricht. pp 333-344.
Boeschoten, W.C. and Fase, M.M.G. (1992). *The demand for large banknotes.* Journal of Money, Credit and Banking, 24(3), 319-337.
Bolten, J. (1987). *Dutch Banknote Design. A compendium.* Including a list of banknotes issued by De Nederlandsche Bank draw up by P. Soetens. De Nederlandsche Bank NV. Stenfert Kroese. Leiden/Amsterdam.
Bolten, J. (1999). *Dutch Banknote Design 1814-2002. A compendium.* Includes: Grolle, J.J. and Koeze, P. *Catalogue of Dutch banknotes 1814-2002.* De Nederlandsche Bank NV. Primavera Press. Leiden.
Bosman, R. (1996). *Discussie over de beoordeling van bankbiljetten op gezondheidsaspecten, milieu(aansprakelijkheids)aspecten, produktveiligheid en produktaansprakelijkheid.* (Discussion on the evaluation of banknotes on health, environmental (liability) aspects of product safety and product liability). Study ordered by De Nederlandsche Bank NV. TNO Milieu, Energie en Procesinnovatie. Apeldoorn. Not Published.
Bourassa, F. and Warren, M. (2016). The Money Maker: My Adventures as the World's Most Wanted Counterfeiter. HarperCollins.
Bouhdaoui, Y. Bounie, D. and Van Hove, L. (2013). *When do plastic bills lower the bill for the central bank? A model and estimates for the U.S.*. Journal of Policy Modeling, 35(1), 45-60.
Bowles, C. and Box, J. (2011). *Undercover User Experience Design.* New Riders.
Brase, G.L. and Richmond, J. (2004). *The White-Coat Effect: Physician Attire and Perceived Authority, Friendliness, and Attractiveness.* Journal of Applied Social Psychology, 34(12), 2469-2481.
Brion, R. and Moreau, J.L. (2001). *A Flutter of Banknotes From the First European Paper Money to the Euro.* Mercatorfonds. Antwerp.
Brits, H. and Winder, C. (2004). *Payments are no free lunch*. DNB Occasional Studies, 3(2).
Brown, D. (2007). *Paying with paper.* Movie. www.youtube.com/watch?v=3Vz_YTNLn6w
Buitelaar, T. (2008). *The Colour of Soil.* De Nederlandsche Bank NV. DNB Cash Research Seminar. Amsterdam.
Bureau of Engraving and Printing (2013). www.moneyfactory.gov.
Business Dictionary (2015). http://www.businessdictionary.com
Buxton, B. (2007). *Sketching user experiences. Getting the design right and the right design.* Morgan Kaufmann. San Francisco.
Byatt, D. (1994*). Promises to Pay - The First Three Hundred Years of Bank of England Notes*. Spink & Son Ltd. London.

C Cartwright, C.R., Duffy, C.M. and Wang, H. (2014). *Microscopical examination of fibres used in Ming dynasty paper money.* Technical Research Bulletin. Volume 8. The British Museum. London.
Chandler, D. and Munday, R. (2011). *A Dictionary of Media and Communication.* Oxford University Press. Oxford.
Church. S. and Setlakwe, L. (2004). *Analysis of counterfeits and public survey results as design input.* Optical Security and Counterfeit Deterrence Techniques V, 16th International Symposium Electronic Imaging: Science and Technology. San Jose.
Clifton, R. (2009). *Brands and branding.* The Economist in association with Profile Books Ltd. London.
Clain-Steffanelli, E. (1975). *Chartered for Progress: Two Centuries of American Banking, A Pictorial Essay.* Acropolis Books Ltd.Washington D.C.
Collins, B.L., Mayerson, S.E. and Worthey, J.A. (1985). *Noticeability of features of secure documents.* Technical Report.US Bureau of Engraving and Printing. Washington.
Contini, D., Crowe, M., Merritt, C. and Oliver, R. (2011). *Mobile Payments in the United States Mapping out the Road.* Federal Reserve Bank of Atlanta and the Federal Reserve Bank of Boston. Atlanta.
Cramer, J.S. (1983). *Currency by denomination.* Economics Letters, 12.
Cramer, J.S. (1986). *De optimale coupure-opbouw* (The optimal denomination structure). In: M.M.G. Fase, J.R. Steinhauser and Joh. de Vries (eds). Het Nederlandse Bankbiljet in zijn Verscheidenheid. Kluwer. Deventer.
Cramsie, P. (2010). *The Story of Graphic Design.* The British Library. London.
Crowley, J. (2016). *The 10 Most Notorious Counterfeiting Operations of the Last 100 Years.* IBDA Insight, 11, 41-43.
Currency News (2016a). *'Appy Days' for banknotes.* 14(7), 6-7.
Currency News (2016b). *Optical Authenticity Features: User Analysis with Design in Mind.* 14(4), 8-9.
Currency News (2009). *Louisenthal Leads the Way with New Hybrid Substrate.* 7(5), 9.
Currency News (2008). *The Dutch Opt for Sustainable Banknotes.* 6(6), 6.

D Davies, G. (2002). *A History of Money from Ancient Times to the Present Day.* Third Edition. University of Wales Press. Cardiff.
De Bont, C., Den Ouden, E., Schifferstein, R., Smulders, F. and Van der Voort, M. (2013). *Advanced design methods for successful innovation.* Design United.
Delanty, G. (1995). *Inventing Europe: idea, identity, reality.* Palgrave Macmillan.
De La Rue Currency (2014). *Portraits on banknotes.* IBDA Insight, 7, 21-23.
De Nederlandsche Bank (2017a). *Cash payments should remain must remain possible in the Netherlands.* DNBulletin.
De Nederlandsche Bank (2017b). *Daling aantal valse eurobiljetten.* (Decline of false euro notes.). Press release.
De Nederlandsche Bank (2016). *Point of Sale payments in 2015 Results of De Nederlandsche Bank and Dutch Payments Association study into the use of cash and debit cards in the Netherlands in 2015.* http://www.dnb.nl/en/binaries
De Nederlandsche Bank (2015a). *Card or cash? Customer preferences dictate retailers.* Includes factsheet: *Cash – retailers' behaviour and perception. Outcome of DNB study into retailers' behaviour and perception with regard to cash, conducted jointly with Panteia.* www.dnb.nl.
De Nederlandsche Bank (2015b). *Valse biljetten.*(Counterfeited banknotes). http://www.dnb.nl/betalingsverkeer/eurobankbiljetten/valse-biljetten/index.jsp
De Nederlandsche Bank (2015c). *Press release: MOB meeting: ambition to achieve instant payments in 2019.* http://www.dnb.nl/en/news/news-and-archive/persberichten-2015/dnb322416.jsp
De Nederlandsche Bank (2013). *How do the Dutch rate euro banknotes?* DNBulletin. 19 September 2013. www.dnb.nl.
De Nederlandsche Bank (2012). *Activities of De Nederlandsche Bank in the euro cash cycle.* Brochure by DNB Cash Expertise Centre. Amsterdam.
De Nederlandsche Bank (2010a). *De geschiedenis van ons geld.* (The history of our money). De Nederlandsche Bank NV. Amsterdam.
De Nederlandsche Bank (2010b). *Increase in number of counterfeit euro banknotes in the Netherlands.* Press release. http://www.dnb.nl/en/news/news-and-archive/persberichten-2010/index.jsp
De Nederlandsche Bank (2009). *Latest developments in payments and settlements.* Quarterly Bulletin June 2009. Amsterdam.
De Nederlandsche Bank (2007). *Actuele ontwikkelingen in het betalings- en effectenverkeer.* (Latest developments in payment and settlement systems.) DNB/Kwartaalbericht. Amsterdam.
De Nederlandsche Bank (1978). *Beschrijving van bankbiljetten.* (Description of banknotes.) De Nederlandsche Bank NV. Amsterdam.
De Rivaz, M. (1997). *The Swiss banknote: 1907-1997.* Genoud.
Desmet, P.M.A. (2002). *Designing Emotions.* Doctoral dissertation. Delft University of Technology, Department of Industrial Design. Delft.
Deutsche Bundesbank (1995). *Von der Baumwolle zum Geldschein. Eine neue Banknotenserie entsteht.* (From cotton to banknote. Creating a new series of banknotes.) Frankfurt.
Dickinson, C.W. (1895). *Copper, steel and banknote engraving.* Popular Science Monthly.
Di Muro, F. and Noseworthy, T.J. (2013). *Money Isn't Everything, but It Helps If It Doesn't Look Used: How the Physical Appearance of Money Influences Spending.* Journal of Consumer Research, 39(6), 1330-1342.
Dinse, H.R. (2008). *Haptic banknote design*. In: Human Haptic Perception Basics and Applications, edited by Grunwald, Martin. Birkhäuser.
DiNunzio, L.A. and Church, S.E. (2002). *Evaluating Public Awareness of New Currency Design Features.* Proceedings of SPIE, Optical Security and Counterfeit Deterrence Techniques IV. Volume 4677. San Jose.
Drupsteen, J.T.G. (1986). *De levensloop van een bankbiljet* (The life course of a banknote). Includes interview with Robert Oxenaar. Video production, broadcasted by the AVRO.

E Eagleman, D. (2017). *Money and our minds: can neuroscience stop counterfeiting?* Financial Times. 1 March 2017. https://www.ft.com
Ebbinghaus, H. (1885). *Über das Gedächtnis. Untersuchungen zur experimentellen Psychologie.* (About the memory. Studies on experimental psychology). Leipzig: Verlag von Duncker & Humblot.
Ekman, P. (1972). *Universal and cultural differences in facial expressions of emotion.* In Cole, J. (Ed.): Nebraska Symposium on Motivation, 19 (pp 207-282). University of Nebraska Press. Lincoln.
Eom, J.S. and Kim, M.S. (2015). *Design Strategies for Security Documents: Based on Contradictory Cognitive Needs.* Bulletin of Japanese Society for the Science of Design, 61(5), 5-11.
European Blind Union (2008). *Objective: how to identify Euro notes? Identification Features and Methods.* www.euroblind.org. Purchased August 2008
European Blind Union (1999). *Handling the euro with ease and confidence: the needs of the visually impaired people.* EBU Euro Group. Brussels.
European Blind Union (1995). *Currency Design for Visually Impaired People.* London.
European Central Bank (2017a). *Modelling euro banknote quality.* ECB Economic Bulletin, 6, 66-89.
European Central Bank (2017b). *Survey on the Use of Cash by Household.* European Central Bank. Frankfurt.
European Central Bank (2016). *ECB ends production and issuance of €500 banknote.* Press Release. www.ecb.europa.eu.
European Central Bank (2015a). *Het nieuwe bankbiljet van €20.* (The new euro 20 banknote.) Leaflet. European Central Bank. Frankfurt.
European Central Bank (2015b). *New €20 banknote unveiled in Frankfurt today.* News & Events. www.ecb.int.
European Central Bank (2015c). *Security features.* www.ecb.europa.eu.
European Central Bank (2014). *Discover the new €10 banknote.* European Central Bank. Frankfurt.

European Central Bank (2013a). *Decision of the European Central Bank of 19 April 201 on the denominations, specifications, reproduction, exchange and withdrawal of euro banknotes.* Official Journal of the European Union. 30.4.2013.
European Central Bank (2013b). *Biannual information on euro banknote counterfeiting.* Press release, 19 July 2013. Frankfurt.
European Central Bank (2013c). *The Europa series of banknotes. The information campaign and experience to date.* Slide presentation by A. McCallum to Intergraf Security Printers International Conference and Exhibition. Vienna.
European Central Bank (2013d). *Environment, health and safety.* www.ecb.europa.eu/euro/banknotes/environmental.
European Central Bank (2013e). *New face of the euro. Discover the new €5 banknote.* Information leaflet.
European Central Bank (2012). *Tenth anniversary of the euro banknotes and coins.* Press kit. Frankfurt.
European Central Bank (2011). *The use of euro banknotes - Results of two surveys among households and firms.* Monthly Bulletin. April 2011. Frankfurt.
European Central Bank (2010a). *Decision of the European Central Bank of 16 September 2010 on the authenticity and Fitness checking and recirculation of euro banknotes.* ECB/2010/14. 2010/597/EU. Frankfurt.
European Central Bank (2010b). *Annual Report 2009.* Frankfurt.
European Central Bank (2008). *Euro banknotes - A tangible symbol of integration.* Monthly Bulletin. 10th Anniversary of the ECB. Frankfurt.
European Central Bank (2007b). *How the euro became our money. A short history of the euro banknotes and coins.* Frankfurt.
European Central Bank (2006). *The second series of euro banknotes.* Annual Report 2005. Frankfurt.
European Central Bank (2004a). *Euro Banknotes: first years of experience.* Monthly Bulleting. April 2004. Frankfurt.
European Central Bank (2004b). *Feel Look Tilt.* Leaflet explaining the colour changing ink in the euro 50 banknote and the gold coloured stripe in the 20 euro banknote. Frankfurt.
European Central Bank (2003). *Euro banknote design exhibition.* Frankfurt.
European Central Bank (2001). *The Euro Our Money.* Leaflet explaining the low and high denominations. Frankfurt.
European Commission (2015). *Flash Eurobarometer 429. The euro area.* Conducted by TNS Political & Social at the request of the European Commission.
European Monetary Institute (1996). *Selection of the euro banknote designs.* Press Release 13 December 1996. European Monetary Institute. Frankfurt.
Evans, A., Gallagher, G. and Martz, A. (2015). *Banknote Stakeholder Engagement.* Bulletin. September Quarter 2015. Reserve Bank of Australia. Sydney.

F

Fase, M.M.G, Steinhauser, J.R. and De Vries, J. (red.) (1986). *Het Nederlandse bankbiljet in zijn verscheidenheid.* (Dutch banknotes in its diversity). Monetaire Monografieën Nr. 6. Kluwer. Deventer.
Federal Reserve Bank of New York (2008). *How Currency Gets into Circulation*. http://www.newyorkfed.org/aboutthefed/fedpoint/fed01.html
Firth, A.V., and Church, S.E. (2009). *Building better banknotes. The role of scientific research at the Bank of Canada.* Journal of Documents & Identity, 28, 22-25.
Firth, A. and Balodis, E. (2011). *Designing better banknotes. The role of perception studies.* Keesing Journal of Documents & Identity, 36, 1-4.
Fish, T. and Whymark, R. (2015). *How has cash usage evolved in recent decades? What might drive demand in the future?* Quarterly Bulletin 2015 Q3. Bank of England. London.
Flach, J.M. and Dominguez, C. O. (1995). *USE - Centered Design: Integrating the User, Instrument, and Goal.* Ergonomics in Design: The Quarterly of Human Factors Applications. 3(3), 19-24.
Ford, H. and Crowther, S. (1922). *My Life and Work.* Doubleday, Page & Company. New York.
Folga-Januszeweska, D., editor (2006). *Small scale-High art.* Prepared for the Polish Security Printing Works (PWPW). Lech Majewski Studio. Warsaw.
Fong, D. (2011). *Europeans don't bond with politically correct euro notes.* Deutsche Welle, http://www.dw-world.de.
Foqué, R. (2010). *Building Knowledge in Architecture.* University Press Antwerp. Antwerp.
Frascara, J. (2002). *People-centered design. Complexitiy and Uncertainties.* In: Frascara, J. (editor). *Design and the Social Sciences.* Taylor and Francis. London and New York.
Frascara J., Meurer, B., Van Toorn, J. and Winkler, D. (1997). *User-Centered Graphic Design: Mass Communication And Social Change.* CRC Press.
Fukuda, S. (2016). *Fundamental research on improving the tactile properties of printed sheets.* Power Point Presentation presented at Banknote 2016, Washington. Research Institute of National Printing Bureau. Tokyo.
Fürbach, M. (2017). *Measuring the Extent of Counterfeiting.* Currency News, 15(6), 4-7.

G

Garret, J.J. (2002). *Elements of User Experience. User-Centered Design of the Web.* Peachpit Press.
Gilbert, E. (1998). '*Ornamenting the facade of hell': iconographies of 19th-century Canadian paper money.* Environment and Planning D: Society and Space, 16, 57-80.
Gilbert, E. and Helleiner, E., eds. (1999). *Nation-States and Money: The Past, Present and Future of National Currencies.* Routledge. London.
Giori, F. (2014). *Banknote Artistry and Design Evolution.* IBDA Insight, 7, 6-8.
Goethe, J.W. (1810). *Theory of Colours.*
González Candela, E., López González, M. and Terborg Del Rosal, H.F. (2014). *MATUSALEN; $ 200 peso commemorative banknote circulation.* Banco de México. Conference on Optical Document Security. San Francisco.

Gould, J.D. and Lewis, C. (1985). *Designing for Usability; Key Principles and What Designers Think.* Communication of the ACM, 28(3), 300-311.
Gourville, J.T. (2006). *Eager Sellers and Stony Buyers: Understanding the Psychology of New-Product Adoption.* Harvard Business Review, 84(6), 98-106.
Graham, C. (2016). *New £5 notes contain animal fat, says Bank of England, drawing anger from vegans and vegetarians.* The Telegraph. www.telegraph.co.uk
Green, P. and Srinivasan, V. (1978). *Conjoint analysis in consumer research: Issues and outlook.* Journal of Consumer Research. 5, 103 -123.
Grolle, J.J. (1991). *Geschiedenis van het Nederlandse bankbiljet.* (History of Dutch banknotes.) Laurens Schulman BV. Bussum.

H
Handelsblatt (2015). *So viel Euro-Falschgeld wie nie in Deutschland.* (Never so much euro counterfeits in Germany.) 20 July 2015.
Hardwick, B. (2002). *Lifecycle Assessment of Polymer Banknotes.* Note Printing Australia. Presented at XVII Pacific Rim Banknote Printers'Conference. Bangkok.
Havermans, O. (2014). *Een pinautomaat met gemeentelijke steun* (An ATM with support of the municipality). Trouw. Amsterdam.
Heath, C. and Heath, D. (2007). *Made to Stick: Why Some Ideas Survive and Others Die*. Random House.
Heeger, D. (2007). *Signal Detection Theory.* Department of Psychology. New York University.
Heeremans, C. (1995). *Bepaling van hexamethyleendisocyanaat in bankbiljetten D3*. (Determination of hexamethylene diisocyanate in banknotes D3.) TNO Milieuwetenschappen. Study ordered by Joh. Enschedé Security Printing. UNPUBLISHED.
Heinonen, A. (2017). *Banknote Ethics Initiative: a Collective Action between Suppliers and Central Banks.* Currency News, 15(5), 6-7
Heinonen, A. (2015). *The First Euros. The creation and issue of the first euro banknotes and the road to the Europa series.* Suomen Pankki and the European Central Bank. Bookwell Ltd. Porvoo.
Heinonen, A. (2009a). *Lessons in Banknote Communications.* Currency News, 7(12), 6-7.
Heinonen, A. (2009b). *Lessons for Today from the History of Money.* Currency News, 7(4), 5-10.
Heinonen, A. (2007). *The euro banknotes: recent experiences and future challenges. European Central Bank.* Presented at Currency Conference, Bangkok. Reported in De Heij (2007). Programme of Requirements: a powerful tool to develop new, secure banknotes. De Nederlandsche Bank NV. Conference on Optical Security and Counterfeit Deterrence. San Francisco.
Helleiner, E. (2002). *One Money, One People? Political Identities and the Euro.* In "Before and Byeond EMU", edited by Crowley, P.M. Routlidge. London.
Helmke, U., Mennicken, R. and Saurer, J. (1979). *Systems and Networks. Mathematical Theory and Applications.* Proceedings of the Conference on Algebraic, Arithmetic, and Categorial Methods in Computation Theory Held. Berlin.
Hentsch, J.C. (1973*). La circulation des coupures qui constituent une monnaie.* (Denominations that constitute a currency). Journal de la Société de Statistique de Paris, 114, 279-293.
Hernandez, L., Jonker, N. and Kosse, A. (2014). *Cash versus debit card: the role of budget control.* DNB Working Paper, 429.
Hesse-Biber, S.N. and Leavy, P. (2010). *The Practice of Qualitative Research.* Sage Publications, Inc. Thousand Oaks.
Hewitt, V.H. (1994). *Beauty and the Banknotes*. British Museum Press. London.
Hewit, V.H. and J.M. Keyworth (1987). *As good as gold: 300 years of British bank note design.* British Museum Publications. London.
Hoevenagel, R., Van Marwijk, M. , Wils, J. and Bolle, H. (2015). *Retailers en hun contante geld. Een onderzoek naar het gebruik en de beleving van retailers.* (Retailers and their cash. An investigation into the use and perception of retailers). Panteia. Zoetermeer.
Hoofdbedrijfschap Detailhandel (2008). *Monitor betalingsverkeer 2008* (Payment system monitor 2008). Den Haag.
Hoofdbedrijfschap Detailhandel (2010). *Monitor betalingsverkeer 2009* (Payment system monitor 2009). Den Haag.
Hoofdbedrijfschap Detailhandel (2012). *Monitor betalingsverkeer 2011* (Payment system monitor 2011). Den Haag.
Hoolhorst, F.W.B. (2012). *Structuring user-centered product development processes.* Ph.D. Dissertation. University of Twente. Enschede.
Hoyer, D. and Macinnis, D.J. (2008). *Consumer behavior.* Sout-Western. Mason. Ohio.
Huijsing, H. (2001). *Van beeld tot drukwerk*. (From image to print.) Nijgh Versluys. Baarn.
Huizinga, J. (1950). *Homo ludens. Proeve eener bepaling van het spel-element der cultuur* (Homo ludens. Determiniation exercise of the play element of culture). In: Verzamelde werken V (Cultuurgeschiedenis III). Edited by Brummel, L. et al. H.D. Tjeenk Willink & Zoon. Haarlem.
Hymans, J.E.C. (2004). *Money from Mars? The euro banknotes and European identity.* Smith College Northampton.
Hymans, J.E.C. (2005). *International Patterns in National Identity Content: The Case of Japanese Banknote Iconography.* Journal of East Asian Studies 5. Lynne Rienner Publishers. Boulder.
Hymans, J.E.C. (2010). *East is East, and West is West? Currency iconography as nation branding in the wider Europe.* Policial Geography 29(2), 97-108.
Hymans, J.E.C. and Fu, R.T. (2016). *The diffusion of international norms of banknote iconography: A case study of the New Taiwan Dollar.* Political Geography. Elsevier.

I IBDA Working Group (2014). *An Introduction to Public Education and Communication on Banknote Design.* International Banknote Designers Association. Lausanne.
IBNS (2016). International Bank Note Society: http://www.theibns.org
Infograhics Zone (2016). *Top 10 Currency Infographics.* http://www.infographicszone.com/economy/top-10-currency-infographics
Infosecura (2007). *Banknote design - lowest common denominator or bold step forward?* Infosecura, 11(31), 7-9.
Isaacson, W. (2011). *Steve Jobs: A Biography.* Simon & Schuster.
Itten, J. (1961). *Kunst der Farbe.* (The Art of Color). Otto Maier Verlag. Ravensburg.
ISO (2016); ISO 45001. *Occupational health and safety.* International Organization for Standardization. Geneva. Switzerland.
ISO (2010a); ISO 9241-210. *Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems.* International Organization for Standardization. Geneva. Switzerland.
ISO (2010b). ISO 26000. *Guidance on social responsibility.* International Organization for Standardization. Geneva. Switzerland.
ISO (2008a); ISO 4217. *Currency codes.* International Organization for Standardization Geneva. Switzerland.
ISO (2008b); ISO 9001. *Quality Management Systems. Requirements.* International Organization for Standardization. Geneva. Switzerland.
ISO (2006a); ISO 14040. *Environmental management - Lifecycle assessment - Principles and framework.* International Organization for Standardization Geneva. Switzerland.
ISO (2006b); ISO 7813. *Information technology -Identification card -Financial transaction cards*. International Organization for Standardization Geneva. Switzerland.
ISO (2003); ISO 7810. *Identification cards - Physical characteristics.* International Organization for Standardization Geneva. Switzerland.

J Jacobsen, J., Kaas, G. and Nielsen, S.T. (2011). *Payment Habits in Denmark.* Working Paper 74. Danmarks Nationalbank. Copenhagen.
Jacobi, H. and Van Beek, B. (1988). *Geld van het Koninkrijk* (Money of the Kingdom). Coöperatieve Vereniging Pampus Associates. Amsterdam.
Jeena, C.S. (2014). *Evolution of polymer banknotes. Pros and cons.* The Authentication Times, 8(25), 7-11.
Jevons, W.J. (1875). *Money and the Mechanism of Exchange.* D. Appleton and Co. New York.
Johnston, D.W., Shah, M. Shields, M.A. and Nicholls, M.E.R. (2009). *Nature's Experiment? Handedness and Early Childhood Development.* Demography, 46(2), 281-301.
Jonker, N. Scholten, A., Wind, M., Van Emmerik, M. and Van der Hoeven, M. (2006). *Counterfeit or genuine: can you Tell the difference?* DNB Working Paper No. 121. De Nederlandsche Bank NV. Amsterdam.
Jonker, N. Kosse, A. Hernández, L. (2012). *Cash Usage in the Netherlands: How Much, Where, When, Who and Whenever One Wants?* Occasional Studies. Volume 10. Number 2. De Nederlandsche Bank NV. Amsterdam.
Jordan, P.W. (2000). *Designing pleasurable products: an introduction to the new human factors.* Taylor & Francis. London.
Judd, D.B. and Wyszecki, G. (1975). *Color in business, science, and industry.* Wiley.
Jungmann-Stadler, F. and Devrient, L. (2009). *Giesecke & Devrient. Banknotendruk 1854-1943*. (Giesecke & Devrient. Banknote Printing 1854-1943.) H. Gietl Verslag & Publikationsservice GmbH. Regenstauf.

K Kaelberer, M. (2004). *The Euro and European Identity: Symbols, Power and the Politics of European Monetary Union.* Review of International Studies, 30, 161-178.
Kahneman, D. (2011). *Thinking, fast and slow.* Farrar, Straus and Giroux. New York.
Kersten, J. (2009). *The Art of Making Money -The Story of a Master Counterfeiter.* Gotham-Penguin.
Keyworth, J. (2001). *Forgery. The Artful Crime. A brief history of the forgery of Bank of England notes.* Bank of England Museum. London.
Keyworth, J. (2013). *The Old Lady of Threadneedle Street.* Quaterly Bulletin 2013 Q2. Bank of England. London.
Kippers, J. Franses, P.H., Van Nierop, E. and Paap, R. (2002). *Hoe betalen we eigenlijk?* (How do we actually pay?). Economisch Statistische Berichten, 22 november 2002. Amsterdam.
Kippers, J. and Franses, P.H. (2003). *Do we need all Euro denominations?* Econometric Institute. Erasmus University. Rotterdam.
Kirkland, J. and Flanagan, D. (1979). *Long-term memory and the value-size hypothesis.* Perceptual and motor skills, 48, 1149-1150.
Klein, M.R., Gadbois, S., Christie, J.J. (2004). *Perception and Detection of Counterfeit Currency in Canada.* Optical Security and Counterfeit Deterrence Techniques V, 16th International Symposium Electronic Imaging: Science and Technology. San Jose.
Klöne, E.J. and Zondervan, I. (2017). *A biennial study about knowledge and appreciation of euro banknotes among the Dutch.* Prepared for De Nederlandsche Bank. Motivaction. Amsterdam.
Knapp, G. (1905). *Staatliche Theorie des Geldes* (The State Theory of Money). Second Edition. Duncker & Humblot. Münich/Leipzig.
Koeze, P. (2003a). *The note-coin boundary.* Currency News, 1(2), 8.
Koeze, P. (2003b). *Het watermark in het Nederlandse bankbiljet 1814-2002* (The watermark in Dutch banknotes). De Nederlandsche Bank NV Amsterdam.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf

Koeze, P. (1990) *A large-scale experiment on the effectiveness of the marks for the blind on Netherlands Banknotes.* De Nederlandsche Bank NV. Banknote Printers' Conference. Rome.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. (1988*). A New Technical Criterion for the Note-Coin Boundary.* De Nederlandsche Bank NV. Amsterdam.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. (1982a). *A graphic method of predicting and constructing moiré patterns.* Optica Acta, 29(5), 595-610.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. (1982b). *Mechanical sorting, data processing and security against counterfeiting.* De Nederlandsche Bank NV. Banknote Printers' Conference. Helsinki.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. (1982c). *The life-length of banknotes. A case study.* Statistica Neerlandica, 36, 187-207.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. (1979). *An accurate statistical estimation of the life-length of f 100-banknotes.* International Statistical Review, 47(3).
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. and Van Gelder, A.H.B.Th. (1983). *The effect of paper fibre direction on the durability of banknotes.* De Nederlandsche Bank. Amsterdam.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Koeze, P. and Van Gelder, A.H.B.Th. (1985). *The effect of coating on the durability of banknotes.* De Nederlandsche Bank NV. Amsterdam.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf
Köppen, W. and Geiger, R. (1936). *Handbuch der Klimatology.* Gebr. Borntraeger.
Kosse, A. (2010). *The safety of cash and debit cards: a study on the perception and behaviour of Dutch Consumers.* Working Paper No. 245. De Nederlandsche Bank NV. Amsterdam.
Kosse, A. (2014). *Consumer payment choices: Room for further digitisation?* Thesis. Tilburg University.
Kosse, A. and Jansen, D. (2013). *Choosing how to pay: The influence of foreign background.* Journal of Banking & Finance, 37, 989-998.
Kranister, W. (1989). *The Moneymakers International.* Black Bear Publishing. Cambridge.
Krishnaswamy, N. (2012). *Development of banknote design: a study of application of indigenous knowledge and innovation.* Bharatiya Reserve Bank Note Mudran Private Limited. Presented at: Participatory Innovation Conference 2012. Melbourne.
Krüger, M. and Seitz, F. (2014). *Costs and Benefits of Cash and Cashless Payment Instruments.* Deutsche Bundesbank. Frankfurt.
Kuijpers, E. (2011). *Ootje Oxenaar. Designer and commissioner.* Nai010 Uitgevers. Rotterdam.
Kuiper, I. (2016). *Duurzaam betalen.* (Sustainable payments). DNB Magazine, 1.

L

Larcin, A., Hanegraaf, R., Jonker, N., Miedema, J. and Mandley, S. (2017). *Life cycle assessment of the Dutch physical payment system.* DNB Working Paper, (forthcoming)
Lauer, J. (2008). *Money as Mass Communication; U.S. Paper Currency and the Iconography of Nationalism.* The Communication Review, 11(2), 109-132.
Lederman, S.J. and Hamilton, C. (2002). *Using Tactile Features to Help Functionally Blind Individuals Denominate Banknotes.* Human Factors Ergonomics Society, 44(3), 413-428
Leibbrandt, G. (2016). *Not all payments are created equal: segmenting the payment landscape.* The Journal of Financial Market Infrastructures, 4(4), 27-40.
Levitt, T. (1965): *Exploit the Product Life Cycle.* Harvard Business Review, 43, 81-94.
Lew, J.J. (2016). *An open letter from Secretary Lew.* http://medium.com/@USTreasury/an-open-letter-from-secretary-lew.
Lindgren, T. (1968). *Riksbankens sedelhistoria 1668-1968.* Stockholm. Rabéen & Sjögren.
Lindsey, E. (2013). *Treasurey Secretary Jack Lew's signature revealed.* Market Place. www.marketplace.org.
Lingnau, A., Pavani, F. and Schwarzbach, J. (2007). *How do People Manipulate Banknotes?* Centre for Mind/Brain Sciences University of Trento. Italy. Confidential.
Reported in 'Banknote design for the visually impaired' (De Heij, 2009).
Lohweg, V. (2012). *Mobile Devices for Banknote Authentication - Is it possible*? Ostwestfalen-Lippen University of Applied Sciences, presented at the conference on Optical Document Security, San Francisco, 18-20 January 2012.
Lönnberg, Å. (2008). *Who signs the banknotes?* Central Banking, 18(3).
Lyutov, V.V. and Yurov, A.V. (2002). *Experience of application of security features for banknotes of the Bank of Russia.* St. Petersburg.

M

Maatschappelijk Overleg Betalingsverkeer (2016). *Bereikbaarheidsmonitor 2016* (Accessibility monitor). Amsterdam.
Malmberg, S., Graaskamp, L. and Balodis, E. (2017). *Banknote wear in Canada. Comparing paper and polymer substrates for a whole series transition.* Keesing Journal of Documents & Identity, 53, 3-8.
Marincovic, C., Pritchard, K. Binder, M. Da Silva, N. (2011*). Life Cycle Assessment of Canada's Polymer Bank Notes and Cotton-Paper Bank Notes.* Prepared for the Bank of Canada by PE masericas ad Tryskele. Boston.
Marx, K. (1867*). Das Kapital* (Capital.) Re-issued in 1974 by International Publishers. New York.
Masuda, O., Marius Pedersen. M. and Hardeberg, J.Y. (2016). *Features contributing to the genuineness of portraits on banknotes.* J. Print Media Technol. Res., 5(1), 53-59.
Masuda, O., Pedersen, M. and Hardeberg, J.Y. (2015). *Effects of awareness to security features on the confidence in banknotes.* J. Print Media Technol. Res., 4(2), 103-110.

Matthijsen, E.E. and Scholten, A.A. (2012). *Inzicht in Cash* (Insight in Cash). DNB-Intern. De Nederlandsche Bank NV. Amsterdam.
McCabe, B. (2016). *Countefeiting and Technology.* Whitman Publishing. Atlanta.
McCallum, A. (2009). *The Eurosytem's Approach to Quantifying the Threat Posed by Counterfeiting.* European Central Bank. Presented at Banknote 2009. Washington.
McCormick, E.J. (1964). *Human Factors Engineering.* McGraw-Hill Book Company. New York.
McLintock, R. and Whymark, R. (2016). *Bank of England notes: the switch to polymer*. Quaterly bulleting 2016 Q1. Bank of England. London.
Melbourne, B. (2008). *The Canadian Banknote Reader for the Blind.* Currency News, 6(9), 9.
Meuer, T. and Martin, J. (2011). *The Eurosystem's effort in the search for a longer lasting banknote.* Billetaria, 9, 22-24.
Michelson, A. (1927). *Studies in optics.* University of Chicago Press. Chicago.
Ministry of Finance of Japan (2012). *The outline of the results of an investigation of the survey about Japanese currency*. http://www.mof.go.jp/currency/research/jittai/kk240618.htm
Ministry of Finance of Japan (2015). www.mof.go.jp/english/
Moggridge, B. (2007). *Designing Interactions.* MIT Press. Cambridge.
Monestier, M. (1983). *Bankbiljetten van de wereld.* (Banknotes of the world). Elsevier. Brussel/Amsterdam.
Mooij, J. and Dongelmans, T. (2004). *Mogen wij even afrekenen? Twee eeuwen betalen in Nederland.* (May we pay? Two centuries of payments done in the Netherlands). Boom. Amsterdam.
Morris, G.R., Copes, H., Perry-Mullis, K. (2009). *Correlates of currency counterfeiting.* Journal of Criminal Justice, 37(5), 472-477.
Morris, P.E. (1988). *Expertise and everyday memory.* In Gruneberg, M.M., Morris, P.E. and Sykes, R.N. (Eds), *Practical aspects of memory: Current research and issues: Vol. 1. Memory in everyday life.* John Wiley. Chicchester.
Moxley, J., Meubes, H. and Brown, B. (2007). *The Canadian Journey: An Odyssey into the Complex World of Banknote Production.* Bank of Canada Review. Autumn 2007. Bank of Canada. Ottowa.
Müller, K. (2011). *Directons for improving the Euro banknotes for elderly people.* Revised Edition of MasterThesis. Beuth Hochschule für Technik. Berlin.
Mundell, R. (2005). *The case for a world currency.* Journal of Policy Modeling, 27(4), 465-475.

N
Nachtstern, M. and Arntzen, R. (2008). *Counterfeiter. How a Norwegian Jew survived the Holocaust.* Osprey Publishing. Oxford.
Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System.* Bitcoin.org.
National Research Council (2007). *A Path to the Next Generation of U.S. Banknotes: Keeping Them Real.* National Academic Press. Washington.
National Research Council (1995). *Currency features for visually impaired people*. National Academy Press. Washington.
National Research Council (1993). *Counterfeit Deterrent Features for the Next-Generation Currency Design.* National Academy Press. Washington.
National Research Council (1987). *Counterfeit Threats and Deterrent Measures.* National Academy Press. Washington.
National Research Council (1985). *Advanced Reprographic Systems: Counterfeiting Threat and Deterrent Measures.* National Academy Press, Washington
Naqvi, M. and Southgate, J. (2013). *Banknotes, local currencies and central bank objectives.* Quarterly Bulletin 2013 Q4. Bank of England. London.
Nederlandse Vereniging van Banken (2004). *Richtlijnen voor een toegankelijke geldautomaat* (Guidelines for an accessible ATM). Amsterdam.
Nederlandse Vereniging van Banken (2005). *Input from the Netherlands Bankers Association on the features of the new euro.* E-mail, 22 August 2005 by Y. Willemsen. Amsterdam. Published in De Heij (2006). *Public feedback for better banknote design.* DNB Working Paper, 104.
Negueruela, D. and Fernández, M. (2008). *Have people learned to love euro banknotes yet?* Slide Presentation. Banco de España. Presented at Currency Conference. Prague.
Nelson, C.R. (2009). *Macroeconomics: an Introduction. Chapter 6 Money, Banks and The Federal Reserve.* Internet Edition 2009. http://faculty.washington.edu/cnelson/macroeconomics.html
Neurensics (2013). *Eyetracking onderzoek* (Eye tracking research). Prepared for De Nederlandsche Bank NV. Amsterdam.
Nickerson, R.S. and Adam, M.J. (1979). *Long-term memory for a common object.* Cognitive Psychology 11(3) Available http://www.sciencedirect.com/science/article/pii/0010028579900136
Nielsen, J. (1995). *10 Usability Heuristics for User Interface Design.* https://www.nngroup.com/articles/ten-usability-heuristics
Norges Bank (2014a). *Motifs for the new banknote series.* Press release. Norges Bank. Oslo.
Norges Bank (2014b*). Norges nye seddelserie: havet*. (Norwegian new banknote series: the sea). Norges Bank. Oslo.
Norman, D.A. (1988). *The Psychology of Everyday Things.* Basic Books. New York.
Norman, D.A. (2005). *Emotional Design*. Basic Books. New York.
Norman, D.A. (2013). *The Design of Everyday Things.* Basic Books. New York.
NOS (2017). *Nieuw 50-eurobiljet is 'gemiste kans'.* (New 50-euro note is 'missed opportunity). http://nos.nl/artikel/2166551-niuew-50-eurobiljet-is-gemiste-kans.html

O
O'Byrne, L. (1996). *Counterfeit experience with a new banknote series.* Central Bank of Ireland. Presented at Banknote Printers' Conference. Budapest.
Oosterlaken, E. (2017). *Design as a process. Why designing a chair is the same thing as designing a website.* Turn the Page. Study Association I.D. Delft Technical University. Faculty Industrial Desing Engineering, 18(60), 33-35.
Ovason, D (2004). *The secret symbols of the dollar bill.* Harper Collins Publishers. New York.

P Pacreu, J. (2008). *Interview with Thomas A. Ferguson, former Director of the Bureau of Engraving and Printing of the United States.* Billetaria, 2(4), 3-4.
Pattanarangsun, P. (2011). *The Optimal Currency Denomination Structure: A Case of Thailand.* Thesis. School of Development Economics. National Institute of Development Administration. Bangkok.
Pavliscak, P. (2015). *The Science of Happy Design*. SXSW 2015.
Payne, J. (2016). *Why there must be substance in banknote style.* IBDA Insight, 12, 15-20.
Payne, L.C. and Morgan, H.M. (1981). *UK currency needs in the 1980s*. The Banker. April 1981.
Pearson, N. (2012). *Increasing banknote durability - Results from the Bank of England's £5 circulation trial.* Bank of England. Presented at DNB Cash Research Seminar. Amsterdam.
Peek, J. (1972). *Plaatjes in leerprocessen.* (Pictures in learning processes). Thesis. University of Utrecht. Drukkerij Elinkwijk. Utrecht.
Penrose, J. and Cumming, C. (2011). *Money talks: banknote iconography and symbolic constructions of Scotland.* Nations and Nationalism, 17(4), 812-842.
Pérez, M. Guinea, S. and Negueruela, J.D. (2014). *The Banco de España's cash survey.* Billetaria, 16, 6-9.
Perron, M., Grimal, J. and Beauchet, J. (2004). *Chips in banknotes for a banknote electronic signature.* Proceedings of SPIE. Optical Security and Counterfeit Deterrence Techniques V. San Jose.
Peters, J.D. (1999). *Speaking Into the Air: A History of the Idea of Communication.* Chicago: University of Chicago Press.
Peters, J.P., Thillou, C. and Ferreira, S. (2004). *Embedded Reading Device for Blind People: a Use-Centered Design.* Proceedings International Symposium on Information Theory 2004.
Pick, A. (1975). *Standard Catalog of World Paper Money*. Krause Publications.
Pick, A. and Schmidt, T.L. (2017). *Standard Catalog of World Paper Money.* Volume 3: Modern Issues 1961-2017. 23th Edition. Krause Publications.
Pilling, D. (2017). *Somalia to print first banknotes in 25 year.* Financial Times.https://www.ft.com.
Pine II, B. J., and Gilmore, J. H. (1999). *The experience economy: work is theatre & every business a stage.* Harvard Business School Press. Boston.
Pollara (2014). *Principles for Bank Note Design.* http://www.bankofcanada.ca/principles-bank-note-design.
Potter, O.B. (1879). *The National Currency and its Origins.* J.J. Little and Co. New York.
Press Turst of India (2017). *Govt plans changing security features of notes every 3-4 years.* 2 April 2017. http://www.hindustantimes.com
Prinsen, M.K. and Van Delft, J.H.M. (1997). *Safety screening study of NLG10/D4; acute oral toxicity testing in rats, repeated-dose dermal irritation testing in albino rabbits, sensitization testing (Maximization test) in guinea pigs, and genotoxicity testing (Ames test).* Study ordered by De Nederlandsche Bank NV. TNO Nutrition and Food Research Institute. Zeist. Unpublished.
Prinsen, M.K. and Van Delft, J.H.M. (1999). Safety screening study of "EURO 200" banknotes; acute oral toxicity testing in rats, repeated-dose dermal irritation testing in albino rabbits, sensitization testing (Maximization test) in guinea pigs, and genotoxicity testing (Ames test). Study ordered by De Nederlandsche Bank NV. TNO Nutrition and Food Research Institute. Zeist. Unpublished.
Pymnts.com (2015). *Denmark Legislates Cashless Society.* http;//www.pymnts.com/news/2015/Denmark-legislates-cashless-society.

R Randsdorp, Y. and Zondervan, I. (2015). *A biennial study about knowledge and perception of euro banknotes among the Dutch.* Prepared for De Nederlandsche Bank. Motivaction. Amsterdam.
Ratcliffe, L. and McNeill, M. (2012). *Agile Experience Design.* New Riders. Berkely.
Raymond, J. (2017). *The Importance of Intaglio in the Authentication of Banknotes by the General Public.* Prepared by Secure Perception Research for International Banknote Designers Association. Birmingham.
Raymond, J. and Jones, S. (2016). *Visually Navigating a Banknote.* University of Birmingham. Power point presentation to the 4th International Banknote Designers Conference. Paris.
Raymond, J. (2015). *Understanding the banknote user.* University of Birmingham. Power point presentation to Currency Conference. Vancouver.
Raymond, J. (2014). *What the public really see.* IBDA Insight, 7, 13-16.
Reif, F. (2008). *Applying Cognitive Science to Education.* MIT Press. Cambridge (MA).
Reserve Bank of Australia (2014). http://banknotes.rba.gov.au/counterfeits.html.
Reserve Bank of New Zealand (2011a). *RBNZ Bank Notes Survey 2010 Consumers*. Nielson.
Reserve Bank of New Zealand (2011b). *RBNZ Bank Notes Survey 2010 Retailers*. Nielson.
Reserve Bank of New Zealand (2016). *New Zealand's banknotes.* http://www.rbnz.govt.nz/notes-and-coins/notes
Resnikoff, S., Pascolinij, D., Etya'ale, D., Kocur, I., Pararajasegaram, R., Pokharel, G.P., and Maritotti, S.P. (2004). *Global data on visual impairment in the year 2002.* Bulletin of World Health Organisation.
Rhea, D. (2003). *Bringing Clarity to the "Fuzzy Front End". A Predictable Process of Innovation.* In: Laurel, B. (editor). Design Research Methods and Perspectives. The MIT Press. Cambridge, Massachusetts. London, England.
Riemann, M. (2014). *Does money make you ill? The risks of living micro-organisms on banknotes.* Keesing Journal of Documents & Identity, 45.
Robertson, F. (2005). *The Aesthetics of Authenticity. Printed Banknotes as Industrial Currency.* Technology and Culture, 46(1), 31-50.
Roos Lindgreen, E., Van Schendel, M., Jonker, N., Kloek, J., De Graaff, L. and Davidson, M. (2017). *Evaluating the environmental impact of debit card payments*, DNB Working Paper, (forthcoming).

Roozenburg, N.F.M. and Eekels, J. (1995). *Product Design: Fundamentals and Methods.* John Wiley & Sons.
Roth, S. (2014). *Coining societies: an inter-functional comparative analysis of the Euro.* The European Journal of Social Science Research. Taylor & Francis Group (Routledge). https://hal.archives-ouvertes.fr/hal-01053519.

S Sabohi, N.M. (2012). *Retailers in Central London - Methods and Procedures for detection of Counterfeit notes.* MSc Dissertation. UCL Department of Security and Crime Science. University of London.
Salmon, C. (2011). *Balancing security and aesthetics: the evolution of modern banknote design.* Speech provided by the Bank of England on 25 October 2011 at the British Nuismatic Society, Warburg Institute. London.
Samual, C. (2009). *Making Bank Notes Accessible for Canadians Living with Blindness or Low Vision.* Bank of Canada Review Winter 2009- 2010. Bank of Canada. Ottowa.
Sands, P. (2016). *Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes.* Working Paper No. 52. Moosavar-Rahmani Center for Business and Government. Harvard Kennedy School.
Schaap, C.D. and Van Vliet, B. (1991). *Vals geld bestrijding* (Fighting counterfeited money). Uitgeverij J.B. van den Brink & Co. Lochem.
Schacter, D. (2011). *Psychology.* Worth Publishers.
Schell, K.J. (2007). *History of Document Security.* In: De Leeuw, K. and Bergstra, J. (2007). *The History of Information Security. A Comprehensive Handbook.* Elsevier. Amsterdam Oxford.
Schiffers, H.E. and Hekkert, P. (2008). *Product Experience.* Elsevier.
Schmiedel, H., Kostova, G. and Ruttenberg, W. (2012). *The social and private costs of retail payment instruments*. Occasional Paper Series No 137. European Central Bank. Frankfurt.
Scholten, A.A. (2017a). *Juridische aspecten van contant geld.* (Legal aspects of cash.) Fincancieel Juridische Reeks, 10. Uitgeverij Paris.
Scholten, A. (2017b). *Decline management: the case of cash. Policy response in the Netherlands and the Nordic countries.* De Nederlandsche Bank NV. Paper presented at the Deutsche Bundesbank Internation Cash Conference. Maninau Islang, 25-27 April 2017.
Scholten, A. (2015). *Paying in cash: a right or favour?* This is an unofficial English translation of the article which was published in Nederlands Juristenblad, 41, 2870 - 2876.
Schoormans, J. P. L. and Robben, H. S. J. (1997). *The Effect of New Package Design on Product Attention, Categorization and Evaluation.* Journal of Economic Psychology, 18, 271-287.
Segendorf, B. and Wilbe, A. (2014). *Does cash have any future as legal tender?* Sveriges Riksbank. Economic Commentaries. NO. 9, 2014. Stockholm.
Sergent, J., Ohta, S. and MacDonald, B. (1992). *Functional neuroanatomy of face and object processing. A positron Emission tomography study.* Brain, 115(1), 15-36.
Setlakwe, L. and DiNunzio, L.A. (2004). *Comparative analysis of public opinion research in the U.S. and Canada*. Bank of Canada and United States Treasury Department, Proceedings of SPIE, Optical Security and Counterfeit Deterrence Techniques V. San Jose.
Shneiderman, B. (1987). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Addison-Wesley Publ. Co. Reading.
Shneiderman, B. and Plaisant, C. (2010). *Designing the User Interface: Strategies for Effective Human-Computer Interaction.* Fifth Edition. Addion-Wesly Publ. Co. Reading.
Sharman, A. (2014). *The bold designs that deter banknote forgers.* Financial Times. 29 April 2014.
Shonfield, P. and Smith, S. (2013). *LCA of Paper and Polymer Bank Notes. Final Study Report.* Prepared for the Bank of England. PE International AG. Sheffield.
Shore, D.I. and Klein, R.M. (2000). *Change blindness: The effect of inversion.* Journal of General Psychology, 127, 27-47.
Sicpa (2017). *Banknotes for all. Intuitive tactile system for the visually impaired.* Sicpa Holding SA. Switzerland.
Simmel, G. (1900). *Die Philosophie des Geldes* (The Philosophy of Money). Duncker & Humblot. Leipzig. Reprint 1990 by Routledge. London.
Simon, H. A. (1956). *Rational Choice and the Structure of the Environment.* Psychological Review, 63(2), 129-138.
Sleeswijk Visser, F. (2009). *Bringing the everyday life of people into design.* Ph.D. Dissertation. Delft University of Technology. Faculty of Industrial Design Engineering. The Netherlands.
Snellen, H. (1862). *Probebuchstaben zur Bestimmung der Sehschärfe*. (Sample letters for determining the visual acuity.) Utrecht.
Snoei, J., Hoevenagel, R., Wils, J. and Brammer, K. (2015). *Kosten van het toonbankbetalingsverkeer in 2014.* (Costs of retail payments in 2014.) Prepared for Stichting Bevorderen Efficiënt Betalen. Panteia. Zoetermeer.
Spencer, C. and Dupuis, D. (2007). *Bank note accessibility features for the blind and vision impaired: the Canadian experience.* Bank of Canada. Currency Conference. Bangkok.
Spool, J.M. (2005). *What Makes a Design Seem 'Intuitive'?* https://articles.uie.com/design_intuitive/.
Springer, K., Subramanian, P. and Turton, T. (2015). *Australian Banknotes: Assisting People with Vision Impairment.* Bulletin. March Quarter 2015. Reserve Bank of Australia. Sydney.
Staal, G. and Wolters, H. (1987). *Holland in Vorm. Vormgeving in Nederland 1945-1987.* (Holland in shape. Design in the Netherlands 1945-1987). Stichting Holland in Vorm. 's-Gravenhage.
Standish, D. (2000). *The Art of Money: The History and Design of Paper Currency from Around the World.* Chronicle Books.
Stevens, M. (2015). *The Link between Public Education and Recognition.* IBDA Insight, 10, 21-23.
Stewart, T. (2008). *Usability or User Experience - What's the difference?* http://www.system-concepts.com/articles/usability-articles/2008/usability-or-user-experience-whats-the-difference.html.

Stewart revers to *Human factors in the use of visual display units,* published in 1976 within "Visual Display Units". British Computer Society (BCS). Displays Group.
Stichting Toegepast Onderzoek Waterbeheer (2014). *Ecologische sleutelfactoren.* (Key ecological factores.) Amersfoort.
Stroop, J.R. (1935). *Studies of interference in serial verbal reactions.* Journal of Experimental Psychology, 18, 643-662.
Stürmer, M. (2015). *Euro ohne Gesicht.* (Euro without a face.). Die Welt. http://www.welt.de/print/welt_kompakt/debatte/article138275813/Euro-ohne-Gesicht.html
Suchack, R. (2013). *Bank of Canada unveils new banknotes from space station.* BBC News. http://www.bbc.com/news/world-us-canada-22367292.
Sullivan, L.H. (1896). *The Tall Office Building Artistically Considered.* Lippincott's Magazine.
Summers, I.R., Irwin, R.J. and Brady, A.C. (2008*). Haptic discrimination of paper*. In: Human Haptic Perception Basics and Applications. Edited by M. Grunwald. Birkhäuser.
Swedberg, C. (2013). *NDSU Researchers Develop Method for Embedding RFID in Paper.* RFID Journal available at http://www.ndsu.edu/ndsu/marinov/docs/RFID_Journal.pdf.
Swiss National Bank (2016a). *The new 50-franc note.* Brochure. Swiss National Bank. Berne.
Swiss National Bank (2016b). *Introductory remarks by Thomas J. Jordan.* Press Conference. Swiss National Bank. Berne.
Swiss National Bank (2007). *Preparation of new banknote series for Switzerland. Project to be pursued further with Swiss graphic artist Manuela Pfrunder.* Press Release. Swiss National Bank. Berne.
Swiss National Bank (2005). *New banknotes project.* News Conference by Niklaus Blattner. Swiss National Bank. Berne.
Swiss National Bank (1995). *The new banknotes. Easy to check.* CHF 50, leaflet. Swiss National Bank. Berne.
Swiss National Bank (1976). *Beschreibung der neuen Banknoten.* Set of leaflets. Swiss National Bank. Berne.

T
Taborsky, M. (2013). *Euro-Shop-Tour.* Power point presentation. Oesterreichische Nationalbank. Vienna.
Talvio, T. (2003). *The Coins and Banknotes of Finland*. Suomen Pankki. Helsinki.
Taylor, V. (2006). *Trends in Retail Payments and Insights from Public Survey Results*. Bank of Canada Review. Spring Issue. Bank of Canada. Ottowa.
The Central Bank of the Republic of Turkey (2005). *The Banknotes of the Republic of Turkey.* The Central Bank of the Republic of Turkey. Ankara.
The Guardian (2016a). *Venezuelans on the removal of the 100-bolivar note: theoughtless, dangerous'*. www.theguardian.com.
The Guardian (2016b). *Open thread: what do you think of Australia's new $5 banknote?* www.theguardian.com.
The Guardian (2013). *New £5 note replaces Elizabeth Fry with Sir Winston Churchill.* www.theguardian.com.
The Royal Mint (2017). *£ 1 counterfeit coins.* http:www.royalmint.com.
Tinker, M.A. and Paterson, D.G. (1932). *Studies of typographical factors influencing speed of reading: IX. Reduction in the size of newspaper print.* Journal of Applied Psychology.
Tinker, M.A. (1963). *Legibility of Print.* Ioawa State University Press. Ames. Iowa.
TNS/NIPO (2004). *Quantitative survey 'Professional cash handlers'*. Prepared for the European Central Bank. Amsterdam.cNot published.
TNS Opinion and Social (2009). *Survey on Cash Handlers in Euro Area Countries 2009.* TNS Opinion & Social. Prepared for the European Central Bank. Brussels. Not published.
Tomasko, M.D. (2012). *The Feel of Steel: the Art and History of Bank Note Engraving in the United States.* American Numismatic Society.
Tomasko, M.D. (2014). *A Brief Look at Bank Note Designn at U.S. Firms in the 19th and Early 19th Centuries.* IBDA Insights, 7, 9-12.
Trachuk, A. and Nikiforova, N. (2008). *The Expedition of Storing State Papers - Goznak. 1818-2008. History in events, facts, destinies.* (In Russian language.) Goznak. Moscow.
Treasury Alliance Group (2014). *Fundamentals of Payment Systems.*www.treasuryalliance.com.
Trichet, J.C. (2004). *The first Vincent lecture.* European Central Bank. Presented at the Vincent van Gogh bi-annual Award for contemporary Art in Europe. Maastricht.

U
United States District Court for the District of Columbia. *Order and Judgement. Civil Action no. 02-864 JR. American Council of the Blind et al., versus Henry M. Paulson JR. Secretary of the Treasury*. Filed 10/03/2008.
Unger, G.A. (2013). *Alverata: hedendaagse Europese letters met wortels in de middeleeuwen* (Alverata: contemporary European characters with roots in the Middle Ages). Doctoral Thesis. Leiden University.

V
Van Boeijen, A.G.C., Daalhuizen, J.J., Zijlstra, J.J.M. and Van der Schoor, R.S.A. (eds.) (2013). *Delft Design Guide.* BIS Publishers. Amsterdam.
Van den Kommer, E., Van der Woude, M. , Petracs, D., Nauta, O. and Terpstra, J. (2012). *How are counterfeits distributed? The situation in the Netherlands.* De Nederlandsche Bank NV. Presented at Banknote 2012. Washington.
Van der Cruijsen, C.A.B., Hernandez, L. and Jonker, N. (2015). *In love with the debit card but still married to cash.* DNB Working Paper, 461.
Van der Cruijsen, C. and Van der Horst, F. (2016). *Payment behaviour: the role of socio-psychological factors.* DNB Working Paper, 532.
Van der Horst, F. (2016). *The halo effect of banknotes - Arguments for good banknote design.* IBDA Insight, 11, 62-63.
Van der Horst, F., Eschelbach, M., Sieber, S. and Miedema, J. (2016). *Does banknote quality affect counterfeit detection? Experimental evidence from Germany and the Netherlands.* DNB Working Paper, 499.
Van der Horst, F. and Matthijsen, E. (2013). *The irrationality of payment behaviour. Conclusions based on literature and direct observation in a virtual-reality and a neuroscientific study.* DNB Occasional Studies, 11(4).

Van der Horst, F., Meeter, M., Theeuwes, J. and Van der Woude, M. (2011). *What is a fit banknote? The Dutch public responds.* DNB Occasional Studies, 9 (4).
Van der Woude, M. (2016). *DNB's authentication app for euro notes.* Keesing Journal of Documents & Identity, 49, 3-6.
Van der Woude, M. and J.M. Geusebroek (2014). *Counterfeit Detection by Image Analysis for Mobile Phones.* De Nederlandsche Bank NV and Perceptech BV. Presented at Conference on Optical Document Security. San Francisco, 29-30 January 2014.
Van Enckevort, T. (2008). *Onze eurobiljetten. Een zoektocht naar onze visuele identiteit.* (Our euro banknotes. A search to our visual identity.) Bachelor's thesis. Akademie voor Kunst en Vormgeving St. Joost. Breda.
Van Erve, P.C.J.F. (1990). *Voorlichting over (valse) bankbiljetten* (Public education on (false) banknotes). Bank- en Effectenbedrijf (39)3. (DNB Reprint 259). Amsterdam.
Van Erve, P. (1998). *Moneta Exotica*. Penningkabinet. Leiden.
Van Goor, M. (2002*). Kleuroblind* (Coleuro blind). NRC. 10 January 2002. Rotterdam.
Van Hove, L. (2001). *Optimal Denominations for Coins and Banknotes*: In: Defense of the Principle of Least Effort. Journal of Money, Credit and Banking, 33(4), 1015-1021.
Van Kasteren, J. (1989). *Bankbiljetten onder de loep.* (Banknotes examined.) Industrieel Ontwerpen, 5(4), 30-33.
Van Kuijk, J. (2010) *Managing Product Usability; How companies deal with usability in the development of electronic consumer products.* Ph.D. Dissertation. Delft University of Technology. Faculty of Industrial Design Engineering. The Netherlands.
Van Kuijk, J. (Editor) (2012). *Design for Usability.* Delft University of Technology. Delft.
Van Loo, P., Binnekamp, J., Van Haeften, E. and Scholten, B. (2001). *Contant geld. De wereld van bankbiljetten en munten* (Cash money. The world of banknotes and coins). Nederlands Instituut voor het Bank-, Verzekerings- en Effectenbedrijf (NIBE-SVV). Serie Bank- en Effectenbedrijf, 44.
Van Marwijk, M. (2016). *Automatische detectieapparatuur* (Automatic detection devices). Study commisioned by De Nederlandsche Bank NV. Panteia. Zoetermeer.
Van Renesse, R. L. (1994). *Optical Document Security.* Artech House. Boston/ London.
Van Renesse, R. L. (2005). *Optical Document Security (Third Edition).* Artech House. Boston/ London.
Van Renselaar, C. (2002). *Van kauri tot euro* (From kauri to euro). De Nederlandsche Bank NV. Amsterdam.
Verhaegen, C. (2014). *Money talks, money signals*. Master Thesis. Faculty of Economics and Business. University of Leuven. Leuven.
Verhoef, L.W.M. (2007). *Why designers can't understand their users: developing a systematic approach using cognitive psychology.* Ph.D. Thesis. Faculty of Social and Behavioural Sciences. University of Leiden.
Visser, J. and Dijkers, W. (2013). *Euro banknotes. A study about awareness and recognition of euro banknotes among the Dutch.* Prepared for De Nederlandsche Bank NV.TNS NIPO. Amsterdam.
Vitsoe (2012). *Dieter Rams: ten principles for good design.*https://www.vitsoe.com/gb/about/good-design.
Vredenburg, K., Isensee, S. and Righi, C. (2002). *User-Centered Design: An Integrated Approach.* Software Quality Institute Series. Prentice Hall PTR.
Vroon, P.A. and Wagenaar, W.A. (1978). *Het Verwarren van Munten* (Confusing coins). In: Proeven op de Som. Van Lochum Slaterus. Deventer.

W
Wadhwa, V. (2017). *What the U.S. can learn from India's move toward a cashless society; India's digital economy is moving ahead of the U.S. due to simple innovations and grunt work.* The Washington Post. https://www.washingtonpost.com.
Walraven, J. and Alferdinck, J.W.A.M. (1997). *Color displays for the colorblind.* IS&T/SD Color Imaging Conference. Scottsdale Arizona.
Walraven, J. (2003). *Color-blind. Seeing the world through different eyes.* Blind Color. Arnhem.
Ward, A. McClintock, R. and Spencer, C. (2008). *Perception testing of portraits on double sided intaglio; a reality check on conventional wisdom.* Bank of England and Bank of Canada. Banknote 2008. Washington.
Waltz, K. (2012). *Fälscher & Falschgeld* (Counterfeiters & Counterfeit money). Battenberg. Regenstauf.
Ware, C. (2008). *Visual thinking for Design.* Elsevier. Amsterdam.
Weber, E.H. (1834). *De pulsu, resorpitione, audita et tactu. Annotationes anatomicae et pshysiologicae.* Leipzig.
Weber, M. (1920). *Economy and society.* Edited by Guenther Roth and Claus Wittich (1978). University of California Press. Berkeley.
Wertheim, A.H. (1990). *Blindentekens op bankbiljetten worden weinig gebruikt* (Blind marks on banknotes are rarely used). Toegepaste Wetenschap TNO Magazine. TNO. Delft.
Wetboek van Strafrecht (2014). Legal articles 208, 209, 210 and 213. http://wetten.overheid.nl.
Wettstein, F. and Lieb, H. (2000). *Lifecycle assessment (LCA) of Swiss banknotes.* Quarterly Bulletin 3/2000. Swiss National Bank. Berne.
Wielandt, R.T. (1998). *The evaluation of document fraud resistance.* In: van Renesse, R.L., ed. Optical Document Security.c2nd ed. Boston. MA: Artech House.
Williams, M. M. and Anderson R.G. (2007). *Currency design in the United States and Abroad: Counterfeit Deterrence and Visual Accessibility.* Federal Reserve Bank of St. Louis. St. Louis.
Wijntjes, M. (2009). *A technical feel model for banknote design based on a literature review.* Study ordered by De Nederlandsche Bank NV and European Central Bank. Unpublished. Delft University of Technology. Faculty of Industrial Design. Delft.
Wolman, D. (2012). *The end of money: counterfeiters, preachers, techies, dreamers - and the coming cashless society.* Da Capo Press. Boston.

Y Yang, J. (2016). *South Korea can offer roeadmap to cashless Asia.* http://uk.reuters.com.

Z Zellermayer, O. (1996). *The Pain of Paying.* Ph.D. Dissertation. Carnegie Mellon University.

Accountability of the images

The copyright holder of the image of a banknote is the central bank, mentioned on the banknote and/or in the accompanying text. Most of the banknotes displayed are retrieved from Banknote World (https://www.banknoteworld.com).
In case the orginal author of an image is known, naming has been applied.
Images retrieved from the internet are often not accounted for, leaving the original author unknown. These images are referred to as 'image from public domain'.
Images created by the author are, in general, included without source reference.

AUTHOR'S PUBLICATIONS

Publications are available at the website of DNB (www.dnb.nl), section 'Research', subsection 'Personal pages' with a link to Hans de Heij.

2018 De Heij, H. (2018). *As people do not check, counterfeiters settle for 50 %.* Conference on Optical Document Security 2016. Reconnaissance International. San Francisco. (Forthcoming).

2017 De Heij, H. (2017). *The Banknote Designer and the Banknote Design Manager. Who does what?* International Banknote Designers Association and De Nederlandsche Bank NV. Lausanne.
Van der Horst, F., De Heij, H., Miedema, J. and Van der Woude, M. (2017). *Perception of public security features on euro banknotes*. IBDA Insight, 13, 53-55.

2016 De Heij, H. (2016a). *Van schelp naar bitcoin.* (From shell to bitcoin). DNB Magazine, 2, 11-13.
De Heij, H. (2016b). *Use-centered Design of Banknotes. Balancing the Use and the Experience.* IBDA Insight, 12, 33-39.
De Heij, H. (2016c). *Banknote design policies.* Keesing Journal of Documents & Identity, 50, 8-14.
De Heij, H. (2016d). *User Experience Functions (UXF) and User Interface Functions (UIF) of Optical Authenticity Features.* Conference on Optical Document Security 2016. Reconnaissance International. San Francisco.

2015 De Heij, H. (2015a). *The Coaster-model for Banknote Designers.* IBDA Insight, 10, 31-34.
De Heij, H. (2015b). *The 4M-model for Banknote Designers.* IBDA Insight, 10, 35-38.
De Heij, H. (2015c). *The Use of Symbolism in Banknotes.* IBDA Insight, 10, 39-46.

2014 De Heij, H. (2014). *Design Freedom: Upgrade or New Series?* IBDA Insight, 7, 36-37.

2013 De Heij, H. (2013a). *Spotting the differences. The revision of the euro 5.* Keesing Journal of Documents & Identity, 40, 6-9.
De Heij, H. (2013b). *Designing banknote identity.* IBDA Insight, 5, 4-6.

2012 De Heij, H. (2012). *Designing banknote identity.* DNB Occasional Studies, 10(3).

2011 De Heij, H. (2011). *Onderzoek naar Europese identiteit* (Study on European identity). DNB Magazine, 9(3), 8-10.

2010 De Heij, H. (2010a). *Banknote design for retailers and public.* DNB Occasional Studies, 8(4).
De Heij, H. (2010b). *Key elements in banknote design; part 1: the product perspective.* Keesing Journal of Documents & Identity, 32, 6-12.
De Heij, H. (2010c). *Key elements in banknote design; part 2: the process perspective.* Keesing Journal of Documents & Identity, 33, 14-18.
De Heij, H.A.M. (2010d*). Innovative approaches to the selection of banknote security features.* De Nederlandsche Bank NV. Conference on Optical Security and Counterfeit Deterrence. San Francisco.
De Heij, H. (2010e). *Public perceptions of banknotes - DNB approach.* De Nederlandsche Bank NV. Presentation to 3rd ECB Central Bank Seminar on Banknotes. Frankfurt.

2009 De Heij, H. (2009). *Banknote design for the visually impaired.* DNB Occasional Studies, 7(2).

2008 De Heij, H. (2008a). *Banknote opinion polls: a method for collecting customer feedback on banknote design.* DNB Cash Seminar. De Nederlandsche Bank NV. Amsterdam.
De Heij, H.A.M. (2008b). *Programme of Requirements: a powerful tool to develop new, secure banknotes.* De Nederlandsche Bank NV. Conference on Optical Security and Counterfeit Deterrence. San Francisco.
De Heij, H. (2008c). *Quality marks in banknote design.* De Nederlandsche Bank NV. Prepared for Materials Committee, European Banknote Committee. Athens.
Van den Kommer, E. and De Heij, H. (2008). *The roles of De Nederlandsche Bank in euro banknote circulation.* De Nederlandsche Bank NV. Amsterdam.

2007 De Heij, H. (2007). *Public feedback for better banknote design 2.* DNB Occasional Studies, (5)2.

2006 De Heij, H. (2006a). *Public feedback for better banknote design.* DNB Working Paper, 104.
De Heij, H. (2006b). *Banknote dimensions and orientation: user requirements.* De Nederlandsche Bank NV. Banknote Printers' Conference. General Meeting. Krakow.
A summary of this article is published in Polish: De Heij, H. (2007). *Wymiary banknotów.* Czlowiek i Dokumenty. Issue 4. Polska Wytwórmia Papierów Wartósciowych SA. Warszawa.
De Heij, H. and Van Gelder, A. (2006a). *Numbers on Banknotes. What is their use?* Keesing Journal of Documents and Identity, 20, 14-18.
De Heij, H. and Van Gelder, A. (2006b). *Numbers on Banknotes. What is their use? Part II.* Keesing Journal of Documents and Identity, 21, 14-18.

2005 De Heij, H.A.M. (2005). *Lifecycle analysis of security features in banknotes; from central bank to retailer.* De Nederlandsche Bank NV. Presented at Banknote 2005. Washington.

2004 De Heij, H. (2004). *Attractive banknotes… a question of design management.* Keesing Journal of Documents & Identity, 9, 20-25.

De Heij, H. and Kippers, J. (2004). *Efficient cash payments with euro coins and banknotes in the Netherlands.* De Nederlandsche Bank NV. Banknote Printers' Conference. Dresden.

2003 De Heij, H.A.M., DiNunzio, L.A., and Strube, O. (2003). *Comparence EUR - USD Banknotes Public's Appreciation and Knowledge.* De Nederlandsche Bank NV, US Treasury BEP and European Central Bank. Presented at Banknote 2003. Washington.

2002 De Heij, H.A.M. (2002a). *A method for measuring the public's appreciation and knowledge of banknotes.* Optical Security and Counterfeit Deterrence Techniques IV. Proceedings of SPIE Vol. 4677. San Jose.

De Heij, H. (2002b). *Durable banknotes: an overview.* De Nederlandsche Bank NV. Presentation of the BPC/Paper Committee to the BPC/General Meeting. Prague.

2000 De Heij, H.A.M. (2000). *The design methodology of Dutch banknotes.* Optical Security and Counterfeit Deterrence Techniques III, Proceedings of SPIE Vol. 3973. San Jose.

1993 De Heij, H. (1993a). *Van blindenstip naar noppentextuur. Waardeherkenning visueel gehandicapten* (From blind marks to dot texture. Value recognition visually impaired). De Florijn, 6(9), 18.

De Heij, H. (1993b). *Publiekskenmerken beter bekend maken* (Increasing awareness of public features). De Florijn. 6(9), 19-21.

1992 De Heij, H.A.M. (1992). *Market-based strategy for the development of new security features for banknote paper.* De Nederlandsche Bank NV, presented at the BPC General Meeting, Amsterdam.

De Heij, H.A.M. and Koeze, P. (1992). *Marktonderzoek bij de Nederlandsche Bank. Is het geeltje succesvol?* (Consumer research at De Nederlandsche Bank. Is the little yellow one a success?). Tijdschrift voor Marketing. 26(3), 6-13.

Van Gelder, A. and De Heij, H. (1992). *The Nederlandsche Bank and banknotes.* De Nederlandsche Bank NV. Amsterdam.

1989 De Heij, H.A.M. (1989a). *Projectmanagement* (Project management). De Ingenieur. 101(5), 12-15.
Also published in: Het Ingenieursblad. Kon. Vlaamse Ingenieursvereniging. 58(12), 45-49.

De Heij, H.A.M. (1989b). *Paspoort versus bankbiljet* (Pasport versus banknote). Compres, 14(7), 20-22.

De Heij, H.A.M. (1989c). *Tolerances in design and mass production of banknotes.* Presentation to Banknote Printers' Conference/Paper Committee. Oslo.

1988 De Heij, H.A.M. and Koeze, P. (1988). *Marktonderzoek en ontwerp van bankbiljetten* (Consumer research and banknote design). Tijdschrift voor Marketing, 22 (3), 28-37.

1987 De Heij, H.A.M. and Koeze, P. (1987). *Leesbare letters* (Readable letters). Compres, 12(6), 55-63.
Also published in Cicero, 4(87), 10-17.
Also published in French: *Des caractères lisible.* Cicero, 4(87), 10-17.

1986 De Heij, H.A.M (1986a). *Selecteren van produktvoorstellen* (Selecting product proposals). De Ingenieur, 98(12), 22-27.

De Heij, H.A.M. (1986b). *De vuurtoren* (The lighthouse). De Florijn, 9(1), 1-6.

De Heij, H.A.M. and Koeze, P. (1986). *Echt of namaak? Van vier naar twintig echtheidskenmerken* (Real or fake? From four to twenty security features). De Florijn, 9(1), 8-10.

1985 Den Butter, F.A.G. and De Heij, H.A.M. (1985). *Opinion surveys on bank notes.* De Nederlandsche Bank NV. Quarterly Bulletin 1985/1. Amsterdam.

1984 De Heij, H. (1984). *Inspiratiebronnen voor ontwerpers* (Sources of inspiration for designers). De Ingenieur, 96(3), 44-49.

Koeze, P. and De Heij, H.A.M. (1984). *The public opinion poll 1983 about Netherlands banknotes*. De Nederlandsche Bank NV. Banknote Printers' Conference, Statistics Committee. London.
Available on: http://www.pkoeze.nl/ListOfPublications.pdf.

1983 De Heij, H. (1983). *Crisis in Industrieel Ontwerpen* (Crisis in Industrial Design). De Ingenieur, 95(9), Annex, 2-4.

SUMMARY

A Model for Use-centered Design of Payment Instruments has been developed. This Model describes the use of a payment instrument by the public. The accompanying label is “Upid-Model” (User Payment Instrument Design). The Upid-Model is proved to be applicable to banknotes and can be used on other means of payments. The Upid-Model describes the human-user interface of a payment instrument.

The Upid-Model has been applied to banknotes, a product known by everybody. A banknote is a traditional payment instrument, tangible and serving as the business card of the nation. Banknotes are a utility product, one size has to fit all. Banknotes are typically a product to be grasped; they have a high proximity to its users, people even carry banknotes on their body. However, the use of banknotes is on the decline, as alternative means of payments seem to fulfil user requirements better than cash. The use of cash in the Netherlands dropped in 2015 for the first time below 50 % of all POS-payments in the Netherlands.
The design of banknotes can be made more user friendly, although this will probably not counteract its declining usage. However, it is not expected that cash will disappear within the next decade and new banknote designs will have to be made. To arrive at more user-friendly banknotes central banks are advised to shift their technology-driven design policy to a use-centered design policy.
The start of a use-centered banknote design is the identification of the banknote's user functions. Ten user functions are identified and laid down in the Upid-Model. User functions of a payment instrument are divided into User Interface Functions (UIFs) and User Experience Functions (UXFs), respectively four UIFs and six UXFs, which are unveiled in two separate chapters. The Model ranks the UIFs and UXFs.

Four research questions have been addressed and all received a positive answer.
1) A model is developed for Use-centered Design of Payment Instruments, the Upid-Model. The Model has been worked out in detail for banknotes.
2) The Upid-Model delivers an appropriate framework to report measurements on the use of banknotes, which reflect the users’ perspective.
3) The Upid-Model is an appropriate tool to underpin a new banknote design and may serve as a framework for the phase of the design definition of a new banknote design, like for example the content of a Programme of Requirements.
4) The Upid-Model is applicable to the use of the design of digital payment instruments.

APPENDIX 1
Overview of the author's studies

Studies initiated, managed, analysed and made public by Hans de Heij on behalf of De Nederlandsche Bank.
* = study managed by other DNB-collegues
** = together with other DNB-colleagues

Year	Object of study	Outsourced to	Reported in
1981*	Appreciation of the NLG 100/Snipe	NIPO, Amsterdam	De Heij and Koeze, 1988
1983**	Appreciation and knowledge of Dutch banknotes (1)	NIPO. Amsterdam	De Heij and Koeze, 1988
1985**	Appreciation and knowledge of Dutch banknotes (2)	NIPO. Amsterdam	De Heij and Koeze, 1988
1985	The recognition of details of three Dutch banknotes	Leiden University. Leiden	De Heij, 2007
1986	The recognition of six Dutch banknotes	Leiden University. Leiden	De Heij, 2007
1986**	Memorising design elements of banknotes	TNO. Soesterberg.	De Heij, 2007
1987	Appreciation and knowledge of Dutch banknotes (3)	NIPO. Amsterdam	Van Kasteren, 1989
1988	Effectiveness of marks for the blind on Dutch banknotes	TNO. Soesterberg.	Wertheim, 1990 De Heij, 2009
1989	Appreciation and knowledge of Dutch banknotes (4)	NIPO. Amsterdam	De Heij and Koeze, 1992
1991	Appreciation and knowledge of Dutch banknotes (5)	NIPO. Amsterdam	De Heij and Koeze,1992
1993	Appreciation and knowledge of Dutch banknotes (6)	NIPO. Amsterdam	De Heij, 1993
1995	Appreciation and knowledge of Dutch banknotes (7)	NIPO. Amsterdam	NRC, 2 april 1996 De Heij, 2002a
1996	Health and safety Dutch banknotes	TNO. Apeldoorn.	De Heij, 2016
1997	Health and safety new NLG 10	TNO. Zeist	De Heij, 2016
1999	Appreciation and knowledge of Dutch banknotes (8)	NIPO. Amsterdam	KVGO1999 De Heij, 2002a
1999	Health and safety euro 200	TNO. Zeist	De Heij, 2016
2002	Appreciation and knowledge of euro banknotes (9)	TNS NIPO. Amsterdam	De Heij, 2006a
2003	Appreciation and knowledge of euro banknotes (10)	TNS NIPO. Amsterdam	De Heij, 2006a
2003	Creating a public friendly foil for euro banknotes	TNS NIPO. Amsterdam	De Heij, 2007
2005	Appreciation and knowledge of euro banknotes (11)	TNS NIPO. Amsterdam	De Heij, 2007
2005	Effectiveness of pictograms on euro banknotes	TNS NIPO. Amsterdam	De Heij, 2006a
2005	Creating a public friendly foil for euro banknotes	TNS NIPO. Amsterdam	De Heij, 2007
2005	The euro and the colour-blind.	Blind Color. Arnhem.	De Heij, 2009

2006	Design instruction for new euro banknotes	180amsterdam. Amsteredam	De Heij, 2007
2007	Appreciation and knowledge of euro banknotes (12)	TNS NIPO. Amsterdam	De Heij, 2008
2008	Evaluation of the colour-blindness compatibility of a 50 euro banknote.	Blind Color. Arnhem.	De Heij, 2009
2009	Appreciation and knowledge of euro banknotes (13)	TNS NIPO. Amsterdam	De Heij, 2009
2010	How people take banknotes. A literature study.	Delft University of Technology. Delft.	-
2011	Appreciation and knowledge of euro banknotes (14)	TNS NIPO. Amsterdam	De Heij, 2012
2012**	Expectations of consumers and retailers about the role of DBN in payment systems.	Motivaction. Amsterdam.	De Heij, 2015
2013**	Appreciation and knowledge of euro banknotes (15)	TNS NIPO. Amsterdam	Visser and Dijkers, 2013 De Heij, 2016d
2015**	Appreciation and knowledge of euro banknotes (16)	Motivaction. Amsterdam	Randsdrop and Zondervan, 2015 De Heij, 2016d
2016**	Authenticity check and confidence in public authenticity features of euro banknotes	Motivaction, Amsterdam	Van der Horst, De Heij, Miederma and Van der Woulde (2017b)
2017**	Appreciation and knowledge of euro banknotes (17)	Motivaction. Amsterdam	Klöne and Zondervan, 2017

APPENDIX 2
An Upid-Model-based checklist of user requirements of banknotes

This appendix presents a tentative list of user requirements for each user function of the Model for User-centered Design of Payment Instruments, applied to banknotes, the figures A2.1 until A2.14. These user requirements must be transformed into design requirements, preferably in the form of a Programme of Requirements, which is not part of this thesis.
The recommended user requirements include two sets for public authenticity features, respectively for foil features (figure A2.6) and colour features (figure A2.7). Such sets could also be prepared for other public features.

User requirements Denomination scheme (UIF 1)			
Critical users	**User requirements**		**Possible design solution**
Central bank	**1. The series design should be based on 3 ATM denominations (low, mid and high) plus one saving denomination.**		
	1.1	The denominations for daily payments are set by the ATM, usually three denominations (e.g. 10, 20, 50).	Most popular ATM-denominations withdrawn by public (e.g. 20 and 50). Lowest ATM-denomination is also lowest payback note for retailers (e.g. 10).
	1.2	One saving denomination. There should be a clear gap between denominations for daily payments and a saving denomination (e.g. 200, 500 or 1,000).	Larger sizes and additional authenticity features. The saving note should not be used in ATMs or banknote acceptors and may only be changed in a controlled environment like a bank.
Retailers	**2. Retailer needs payback banknotes to ATM denominations.**		
	2.1	Cash payback denomination lower than lowest ATM denomination.	A coin (e.g. 5).
Blind	**3. The number of denominations should be a minimal set.**		
	3.1	Three ATM notes.	10, 20 and 50.
	3.2	One saving denomination.	Total of 4 denominations.

Figure A2.1
User requirements and possible design solutions to a denomination scheme.

User requirements **Denomination features (UIF 1)**			
Critical user	**User requirement**		**Possible design solution**
Public	**1. Currency unit should be clearly visible.**		
	1.1	Name of the currency in full text, on front.	Letter height > 3 mm, in capital.
	1.2	ISO currency code, on front.	Letter height > 3 mm, in capital.
Colour blind	**2. Colours should support value recognition.**		
	2.1	Saturated colours.	Avoid pastel tints, avoid natural colours.
	2.2	Monochrome.	Subordinate colours should leave the dominating colour untouched. People should be able to tell from a banknote colour at a distance of around 3 metres.
	2.3	Clear difference between consecutive denominations.	Opposite in colour wheel.
	2.4	Clear difference between denominations having one or more digits in common, like 10 and 100.	Should not be contiguous in colour wheel.
	3. Images should support value recognition.		
	3.1	Clear silhouettes.	Different silhouettes within series.
	3.2	Images from different categories.	
Partially sighted	**4. Numerals should be conspicuous and readable**		
	4.1	At least one large numeral on the front, in an area not covered by wallet, on top of the note.	Standard position. On top.
	4.2	Numeral on top reverse.	> 10 mm.
	4.3	In an area not covered by fingers.	20 mm from corners.
	4.4	Large numerals.	> 22 mm.
	4.5	Clear letter type.	Sans-serif, no outlines etcetera.
	4.6	Numeral in colour of the note.	Numeral more saturated, solid print (100 % coverage).
	4.7	High contrast between numeral and background.	Print Contrast Ratio (PCR) > 70 %. Homogenous background.
	4.8	Both positive and negative numerals.	Alternate positive and negative on consecutive denominations, especially payback notes.
	4.9	Clear differences between denominations.	One negative and one positive numeral, alternate between consecutive denominations.
	4.10	Keep numerals on the same location.	Numerals part of basic layout.
Blind	**5. Dimensions should be clearly distinguishable.**		
	5.1	Clear tactile difference between consecutive denominations.	Increasing length increment payback notes: 7 mm, 8 mm, 9 mm.
	6. Second feature should assist blind with recognition.		
	6.1	Tactile structure at edge.	Use dots and lines, alternate short and long edges. High relief with sharp slopes. (for public feel feature: regular patterns are preferred).
	6.2	Wish: if electronic reader, it should work on both ends.	

Figure A2.2
User requirements and possible design solutions concerning banknote's denomination features.

User requirements **Handling features (UIF 2)**			
Critical user	**User requirement**		**Possible design solution**
Public	**1. Denominations should have a practical size (not too small, not too large).**		
	1.1	Should fit in wallet.	Height: 65 mm > H < 75 mm. Width: 120 mm> W < 160 mm.
	1.2	Horizontal note orientation.	Front: horizontal (landscape style)
	1.3	Firm grip (not too smooth).	Roughness Bendtsen: 525 ml/min, Air permeability Bendtsen: < 0.5 ml/min.
	2. Using an ATM should be pleasant.		
	Remarks		
	-	*Clean notes from clean machine.*	*ATM cleaned once a week.*
	-	*Verification of amount at one glance.*	*Offer notes slightly shifted, 2 mm.*
	-	*Able to specify denominations.*	*ATM accepts denomination specification.*
	3. Using a banknote acceptor should be univocal.		
	3.1	Single note height.	Height: 65 mm < H < 75 mm.
	Remarks		
	-	*Vertical note orientation.*	*Reverse: vertical (portrait style).*
	-	*Low false acceptance rate*	*Small technical variations in original banknotes.*
Blind	3.3	Recognise front and top.	Smooth mark on front, e.g. foil. Tactile element on top.
Retailer	**4. It should be possible to insert banknotes quickly and safely in safety box.**		
	4.1	Short edge feeding.	Single note height.
	Remarks		
	-	*All orientations possible.*	-
	-	*Feed notes one-by-one.*	-
	-	*Registration/clearance to operator.*	-
	-	*Notes cannot be taken out (safe).*	-
Retailer	**5. It should be possible to insert banknotes quickly and safely in cash-in machines.**		
	5.1	Short edge feeding.	Single note height.
	5.2	Clear insert instruction on notes.	Vertical orientation, feeding arrow.
	Remarks		
	-	*One note at the time.*	-
	-	*All orientations possible.*	-
	-	*Confirmation of deposit.*	-
	-	*Notes cannot be taken out (safe).*	-

Figure A2.3
User requirements and possible design solutions concerning banknote's handling features.

User requirements **Authenticity features - retail (UIF 3)**			
Critical	**User requirement**		**Possible design solution**
Retailer	**1. A feature/detector combination should be offered by central bank.**		
	Remarks		
		Automatic device, option 1: low price and relative high false acceptance	*E.g. metameric barcode using laser light scanner of retailer.*
		Automatic device, option 2: medium price and no false acceptance	*E.g. taggant in paper like DNA-grown plants.*
	2. It should be possible to authenticate banknotes with automatic devices.		
	Remarks		
	-	*Keep production specifications within limits.*	
	3. It should be possible to authenticate banknotes by human assist detection devices.		
	3.1	Human-assisted detection: low price, no energy supply needed, like electricity or batteries.	E.g. foil and polarisation filter.
	4. Avoid		
	4.1	Micro-texts, tool: magnifier	No micro-texts.
	4.2	UV-features, tool: UV-lamp	Note is completely UV-dull.

Figure A2.4
User requirements and possible design solutions concerning banknote's authenticity features for retailers.

User requirements **Authenticity features - public (UIF 3)**			
	User requirement		**Possible design solution**
Public	**1. Banknotes should trigger at one glance if it is suspect**		
	1.1	First impression of note is real or fake.	- Substrate properties - Paper tint - Grey tints - Detailed line patterns (e.g. scan and screen traps)
	2. Checking features should be self-explaining		
	2.1	Optimal visible.	- Feature stands out. - Eye goes from left to right. - Rectangular size, about 30 mm x 15 mm.
	2.2	Feature should be checkable without any instruction (intuitive approach).	- Realistic images. - Easy names. - Fitting the theme (e.g. cross reference). - Unambiguous task. - …
	2.3	Should not take long.	Within 3 s.
	3. Feature should provide a large difference between genuine and counterfeit		
	3.1	Clear difference between hits (genuine judged as genuine) and a miss.	d' > 1.5
	4. Banknotes should have a specific feel		
	4.1	Active: large tactile area.	- Where notes are taken: centre of short edges. Effective tactility.
	4.2	Sleeping: nail scratch feature	- Intriguing pattern.
	5. Banknotes should have look-at features		
	5.1	Active: 3D image	- Lenticular hologram (e-beam written).
	5.2	Sleeping: detailed gravure	- Not obvious.
	6. A smartphone should be able to verify a banknote		
	6.1	Make an image with smartphone and the phone tells genuine or not.	Clear line element areas (without CDS distortions). Positioning markers.
	7. Rather not: look-through		
	7.1	Active: security thread Not covered by fingers	- Thread to be specified. - Not on borders.
	7.2	Sleeping: watermark	- Not obvious.
	8. Rather not: tilt		
	8.1	Active: tilt north-south direction Not covered by fingers	Colour or floating images, to be specified. Not on borders.
	8.2	Passive: tilt north-south direction Not covered by fingers	Colour or floating images, to be specified. Not on borders.

Figure A2.5
User requirements and possible design solutions concerning banknote's authenticity features for public use.

User requirements Foil feature		
User requirement		**Possible design solution**
1. Foil feature should be on the front.		
1.1	A foil contributes to confidence, to the first impression of real or fake.	Not too close to the edge. Not covered by fingers. No preference for left or right.
1.2	Foil should be registered.	Registered foil stripe or a patch.
2. The foil feature is checked in look-at.		
2.1	Do not want to be obtrusive.	Plain, multi-coloured foil. Lenticular hologram. Structured colour.
3. There should be one type of foil features throughout the series.		
3.1	One type of foil feature (for learning and recognition).	One type of foil application.
3.2	Foil should be large.	Foil should be a stripe, foil width: at least 15 mm, optimal 30 mm.
4. The design of foil features should be different on each denomination, but should be part of a family.		
4.1	One type of foil design.	Recognisable outline, details are different.
4.2	Different foils on different denominations (same foil will facilitate fraud).	There is a strong preference for the use of only one type of foil (learning, recognition).
5. For counterfeiters the foil should be difficult to reproduce.		
5.1	A foil design should be split in an area for public usage and a 'counterfeit area'.	Multi-coloured foil. Foil stripe in colour of banknote, and a silver coloured are for public.
5.2	It should be possible to check if a foil matches with the denomination.	Denomination numerals. Colour. Realistic images, matching with theme. No abstract images.
5.3	The counterfeit area should be complex.	Too complex for the public to be checked.
5.4	Clear difference between hits (genuine judged as genuine) and a miss.	d' > 1.5
6. Foil should have other tactile properties than surrounding area.		
6.1	The foil feels different from the rest.	Smooth.
7. In case of holographic image: tilt direction should be north-south.		
7.1	The banknote should be tilted in landscape position and in north-south direction.	The ultimate positions of a banknote are at + 60 ° (north) and - 30 ° (south).
8. In case of holographic image: maximum 3 separate images.		
8.1	There should be two separate images.	To prevent change blindness: one image at + 60 °, no image at 0° (or one image) and one image at - 30 °.
8.2	Create a surprise, a little smile.	One image matches to main image on banknote, one image is a related surprise.
8.3	Good contrast of the hologram.	Hologram in silver coloured foil.
9. Rather not: look-through or tilt.		
9.1	Do not want to be obtrusive.	Look-at features. Holographic images like 3D-effects Floating images. Colour effects (e.g. structured colour).

Figure A2.6
Public user requirements of a foil feature in banknotes. Foil feature should also match with the general user requirements for an authenticity features as listed in figure A2.5.

User requirements **Colour feature**		
User requirement		**Possible design solution**
1. Colour feature should be on the front.		
1.1	A colour feature contributes to confidence, to the first impression whether a banknote is real or fake.	Not too close to the edge. Not covered by fingers. No preference for left or right.
1.2	Colour feature should be registered.	No continuous bands.
2. The colour feature is checked in look-at.		
2.1	Do not want to be obtrusive.	Look-at colour features, like structured colour.
2.2	Feature should have gloss.	Iridescent and metallic inks (silkscreen, offset).
3. There should be one type of colour changing features through the series.		
3.1	The colour changing feature should be large.	Area at least 30 mm x 15 mm (or 450 mm^2).
3.2	Should be one element.	50 (not 5 and 0).
4. The design of colour features should be different on each denomination, but should be part of a family.		
4.1	One type of colour effect design.	Designs should relate to the banknote, e.g. to its colour, denomination or main image.
4.2	Colours can note be remembered.	Colour change should relate to the banknote, e.g. to its colour, denomination or main image.
4.3	Create a surprise, a little smile.	An enhancing, realistic image, part of the banknote design theme. For example, the colour feature is the centre of a flower or eye of an animal.
5. In case of a colour change: the colour change should be obvious.		
5.1	Colour A and B should be visible separately, without merging into one another.	Colour A should be clear at + 60 °, no colour at 0° and colour B should be visible at - 30 °.
5.2	The colour difference between A and B should be $\Delta e > 6$.	Select an appropriate technology, e.g. structured colour (instead of ink pigments).
5.3	Change blindness should be prevented.	One colour matches to main colour of the banknote and one colour is standard through the series.
5.4	Clear difference between hits (genuine judged as genuine) and false alarms (a counterfeit judged as genuine).	$d' > 1.5$
6. In case of colour change: tilt direction should be north-south.		
6.1	The banknote should be tilted in landscape position and in north-south direction.	The ultimate positions of a banknote are at + 60 ° (north) and - 30 ° (south).
7. Rather not: look-through or tilt.		
7.1	Do not want to be obtrusive.	Look-at colour effect features, like structured colour.

Figure A2.7
User requirements to a colour changing feature in banknotes. Colour changing feature should also match with the general user requirements for an authenticity features as listed in figure A2.5

User requirements **Receiving the communication message (UIF 4)**			
Critical user	**User requirement**		**Possible design solution**
Public	**1. Banknote should banknote should convey an identity description.**		
	1.1	Forward looking, a little smile, non-directive.	
	2. Banknote should banknote should convey a motto for the series (derived from an identity description).		
	2.1	Generate ideas on standardised emotions.	1) Satisfaction, 2) Pleasant surprise, 3) Fascination, 4) Desire, 5) Amusement.
	2.2	Name.	- Short intriguing name. Two or three words. - Positive message, verified by public research.
	3. The series should have an appealing name		
	3.1	Derived from motto.	- E.g. Big Five, Bridges linking people. Towers of Europe.
	3.2	Name.	- Short intriguing name. One, two or three words. - Positive message.
	4. The theme of each denomination should be derived from the theme series		
	4.1	Themes from different image categories.	- E.g. human, architecture, animal, plant and product.
	4.2	Different themes for individual notes.	- Themes have similar background.
	4.3	Name.	- Preferable one word, with one or two syllabi. - Intriguing name, not so common and a little funny.
	5. The theme of the public authenticity features should be derived from the denomination theme.		
	5.1	Associated with denomination theme.	- Realistic images. - 2D design. - Clear silhouettes.
	5.2	Name.	- Short intriguing names. One or two syllabi.

Figure A2.8
User requirements and possible design solutions concerning banknote's communication message.

User requirements Identity (UXF 1)			
Critical user	User requirement		Possible design solution
Public	**1. The origin of the banknote is recognised by country, currency and central bank.**		
	1.1	Encoding country/area.	Name of country. Map of country. National symbol: flag, iconic symbol (e.g. building), seal, coat of arms.
	1.2	Encoding currency.	Currency unit: name (local), name (English), symbol, ISO 4217-code.
	1.3	Encoding central bank.	Name of central bank. Place of central bank.
	2. Emotions experienced are selected from one or more the following 5 emotions.		
	2.1	Satisfaction - dissatisfaction.	Iconic building, painting or statue.
	2.2	Pleasant surprise - unpleasant surprise.	Fairy tales.
	2.3	Fascination - boredom.	Birds.
	2.4	Desire - disgust.	Longing to the past. Melancholy.
	2.5	Amusement - contempt.	Some humour, create a little smile. Search tasks.
	3. Seeing the banknote, I notice that …		
	3.1	We feel familiar with…	European Union.
	3.2	We want to be associated with …	Other countries in Europe.
	3.3	We are friends with …	Our neighbours.
	3.4	We are proud of …	Eiffel tower. Tower of Pisa. Big Ben.
	4. Looking at the banknote people will characterise the design by …		
	4.1	Life or objects.	Different categories of life and objects
	4.2	Historic or future oriented.	Abstract, e.g. digital images, mathematical screens.
	4.3	Serious or happy.	Colour full, bright colours. Dancing couple. Musicians, music instruments.
	4.4	Local orientation or open to others.	Invitation to set at a table.
	4.5	Directive or non-directive.	Birds, music (no historic portraits).

Figure A2.9
User requirements and possible design solutions concerning banknote's identity.

User requirements Aesthetics (UXF 2)			
Critical user	User requirement		Possible design solution
Public	**1. A banknote should be beautiful.**		
	1.1	Modern design, but not too trendy.	Appoint designer reflecting the time spirit.
	1.2	Graphic design.	Select applied designer-artist. Do not opt for free artists like painters.
	2. A banknote should be part of a series.		
	2.1	Series should show diversity, should not be too uniform.	
	2.2	Series should tell a story.	
	2.3	Se tenant (connecting) denominations	E.g. bridges can be connected from the different denominations.

Figure A2.10
User requirements and possible design solutions concerning banknote's aesthetics.

User requirements Confidence features (UXF 3)			
Critical user	User requirement		Possible design solution
Public	**1. Banknotes exude confidence.**		
	1.1	Banknote does not look like a voucher or coupon.	
	2. Reading the name of the issuing authority.		
	2.1	Front: Name of issuing authority as known to public.	Height > 3 mm.
	2.2	Reverse: Juridical name.	Use in copyright text: © NAME 20XX. Height > 1 mm.
	2.3	In case of more languages: main language or a common language like English on front, variety on reverse.	-
	3. Reading the name of the place of issue (name of the city).		
	3.1	Front: place of issue.	City name. Height > 2 mm.
	3.2	Wish: front: name of country.	Name of country. Height > 2 mm.
	3.3	Geographic map.	Map of the country/area.
	4. Reading the date of approval and the year of production.		
	4.1	Approval date.	Date of approval proof print (fixed date). Height > 1 mm.
	4.2	Production date.	Date of year of production. Height > 1 mm.
	5. Noticing the approval of the president/governor.		
	5.1	Function of approver.	In text, e.g. President, Governor, Height > 1 mm.
	5.2	Name of governor/president.	In text (no signature), 1 mm > height > 2 mm, smaller than function.
	5.3	Wish: image of governor.	Photo signature, < Ø 8 mm. Not changed when new governor takes over.
	6. Perceiving several confidence design elements, like line-patterns, number, complex holographic structures and register marks.		
	6.1	Should look difficult to counterfeit.	1) Complex (background) line-patterns. 2) Complex part of hologram (next to public part).
	6.2	Banknote number, on front.	Confidence feature.
Central bank	6.3	Quality audit.	Register marks.
Public	**7. Noticing access to actual information by a QR-code.**		
	7.1	Direct information by smartphone.	QR-code on front, connecting to website of central bank.

Figure A2.11
Design requirements and possible design solutions concerning banknote's confidence features.

User requirements Reacting on main image (UXF 4)			
Critical user	User requirement		Possible design solution
Public	**1. The main image on a banknote must be discriminate between denominations.**		
	1.1	A realistic image.	Image from different categories, like humans, fauna, flora, architecture, music.
	1.2	The picture should be nameable, should have a name.	Short term of one or two syllables.
	2. The main image should provide a positive feeling.		
	2.1	In line with identity description.	
	2.2	Based on a positive emotion.	
	3. The main image should trigger a little smile.		
	3.1	Addresses the playing man (homo ludens).	A funny search task.
	3.2	Leads to self-reflection.	A woman looking in a mirror which shows her watermark (French FFR 100, 1939).

Figure A2.12
User requirements and possible design solutions concerning the main image on a banknote.

User requirements Sustainable banknotes (UXF 5)			
Critical user	User requirement		Possible design solution
Public	**1. Banknotes should be environmental friendly.**		
	1.1	Environmental friendly production.	Legal framework sets minimum standards. Extra measures are welcomed.
	1.2	Environmental friendly circulation.	Prevent soiling by pre-coating, varnishing and anti-soil design. Prevent mechanical damages by enforced substrates, polymer or laminates.
	2. The production and circulation of banknotes should not harm a person's health.		
	2.1	Healthy production of banknotes.	ISO 45001. Occupational health and safety.
	2.2	Healthy circulation of banknotes.	
	3. The production and circulation of banknotes should be safe.		
	3.1	Safe production of banknotes.	
	3.2	Safe circulation of banknotes.	ATMs in safe environments. Minimise security transports.
	4. The production of banknotes should follow ethical standards.		
	4.1	No child labour.	Certified suppliers.
	4.2	No bribery.	Certified suppliers.
	4.3	A fair price.	Prepared to pay (a little) higher price.
	5. The circulation of banknotes should follow ethical standards.		
	5.1	Fair labour conditions to CIT-workers.	
	4. Banknote production and circulation should not have a negative impact on the world (green banknotes).		
	4.1	Non polluting	Follow common regulations.
	4.2	Small ecological footprint	Compare footprint to previous issue.
	4.3	Fair price to producers	(Percentage of) fair trade cotton and/or biological not manipulated cotton.
	4.4	No child labour	Follow common standards.

Figure A2.13
User requirements and possible design solutions concerning the sustainability of banknotes.

User requirements Linking to information technology (UXF 6)			
Critical user	User requirement		Possible design solution
Public	**1. An authenticity self-check should be possible with a smartphone.**		
	1.1	Smartphone makes image of a banknote and tells if it is genuine or fake.	DNB's "Genuine or Counterfeit" (2015).
	1.2	Dedicated features in banknotes.	Antenna on banknote, for example by foil printing. By resonance, such an antenna may emit a detectable signal as a reaction on radio waves with a specific frequency.
	1.3	Link an individual banknote to a dedicated website by using wirelessly radio waves (WiFi).	Print WiFi-symbol on banknotes. Apply an antenna with some intelligence.
	2. Up to date data on counterfeiting should be available on line.		
	2.1	Are there counterfeits of this banknote? How may these counterfeits be recognised?	
	2.2	Insight into the nationwide distribution.	A map on the screen of the electronic device.
	3. General information on genuine or counterfeit should be available online.		
	3.1	Link by QR-code on banknote to website of central bank.	Each denomination receives a specific QR-code.
Retailers	**4. Check banknote with barcode scanner at retail check-out.**		
	4.1	Barcode on banknotes which can be read with UPC/EAN product scanner.	Safe barcode on banknotes. For example with part of barcode in wavelength area of barcode scanner (around 770 nm), like for example a 'metameric barcode'.

Figure A2.14
User requirements and possible design solutions concerning banknote's link to information technology.

ACKNOWLEDGEMENTS

This thesis is the result of more than eight years of study. Several people have contributed in various ways. First I would like to thank the organisation I am working for, De Nederlandsche Bank NV, for encouraging this thesis on banknote design, especially by:

- Mr. Jan Binnekamp, head of the Cash Policy Department (DNB).

I also want to thank the former head of the Cash Policy Department of DNB (2002-2008) for his suggestion to start a thesis on banknote design:

- Dr. Ton Roos (European Central Bank).

Working at this thesis was supported by my wife, she provided me her basic remarks and kept things into perspective, which was a great support:

- Drs. Cecilia Dijkstra.

I want to thank my intellectual mentor and inspirer, especially on insights in physics, design, design management and an academic approach:

Dr. Ir. Peter Koeze (DNB, retired 2004).

Writing a publication is a solitary activity and a writer needs feedback. For reading and providing comments on premature drafts, I want to thank my colleagues of DNB's Cash Policy Department.

Originally this study aimed for a use-centered design concept of banknotes. However, without design methodology the proposals could not be underpinned. Therefore, in the second part of my thesis period I focussed on model building. Therefore, I also give credit to my former supervisors and co-supervisor for their interest and remarks in the first part of my thesis period (2008-2015):

- Prof. Ir. Jan Jacobs (Delft University of Technology, Faculty of Industrial Design Engineering), accorded emeritus status in 2012,
- Prof. Dr. Frans Verstraten (University Utrecht, Faculty of Social and Behavioural Sciences), Professor of Experimental Psychology at the University of Sydney, since 2012,
- Dr. Theo Boersema (Delft University of Technology, Faculty of Industrial Design Engineering), retired 2015.

For the second part and the finishing of my thesis I thank my supervisors:

- Prof. Dr. Ron Berndsen (Tilburg University and De Nederlandsche Bank),
- Prof. Dr. Rik Pieters (Tilburg University).

In 2015, professor Ron Berndsen offered me to help me to complete my thesis which I started at Delft University of Technology. I want to thank him especially for his suggestion to link the user functions of a banknote design to the economic functions of money.
Professor Rik Pieters provided several academic suggestions to make my study regarding banknotes applicable on all payment instruments.

ABOUT THE AUTHOR

Hans de Heij (1954) graduated in 1979 at the Faculty of Industrial Design Engineering of the Delft University of Technology. In 1981, he became banknote design manager of new Dutch banknotes at De Nederlandsche Bank. During the period 1981-1997 he managed the introduction of five new guilder banknotes:

- NLG 250/Lighthouse (1986),
- NLG 25/Robin (1990),
- NLG 100/Little Owl (1992),
- NLG 1000/Lap Wing (1994),
- NLG 10/Kingfisher (1997).

For the Eurosystem De Heij was the manager of:

- Euro design contest (1996), contribution of DNB,
- EUR 200/Iron and Glass (2002), origination and zero production,
- Design contest ES2 (2006), contribution of DNB.

The guilder banknotes received much attention, not only because of their outstanding graphic designs, but also for their technical innovations. De Heij contributed several partial design concepts to the guilder banknotes, including technical innovations, like a printed barcode and a corresponding reader, introduced in 1990. He has a number of patents on his name.
De Heij pioneered the inclusion of public (consumer) feedback in banknote designs and he has published several articles on the subject.
De Heij also contributed to the design of the euro banknotes, like its colour scheme. Several other suggestions were wayfinding features, tactile structures and holographic feature with public appeal.

De Heij advised several central banks on banknote design issues, like Kyrgyzstan (1992), Aruba (2007, 2014), Hungary (2009), Norway (2010, 2014) and Mexico (2015). Information exchange on banknote design has been done with Japan (2013, 2016).
De Heij was member of the Paper Committee of the Banknote Printers' Conference (1983-2006). To this committee he was respectively Secretary (1997-2000) and Chairman (2001-2004). He was member of the Materials Committee of the European Banknote Committee (2007-2014).
De Heij was instructor at the training course 'New Developments in Banknote and Currency Management' by Central Banking Publications (2006-2012).
Since 2012 he is member of the committee reviewing publications for the Conferences on Optical Document Security.